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PRESIDENT OF THE ASSOCIATION 1958

SIR ALEXANDER FLECK, K.B.E., F.R.S., was installed as President of the Association for 1958 by Professor P. M. S. Blackett, F.R.S. the retiring President, at a General Meeting of the Committees of Sections held in the Beveridge Hall, Senate House, University of London, on Friday, January 3, 1958. Sir Alexander Fleck, who is Chairman of Imperial Chemical Industries Ltd. and a Fellow of the Royal Society, will preside at the Annual Meeting to be held in Glasgow from August 27 to September 3, 1958, and will deliver his Presidential Address to the Association, at the inaugural meeting on the evening of Wednesday, August 27.

The address delivered by Sir Alexander Fleck on the occasion of his installation is printed in full below.

A REVIEW OF THE SCIENTIFIC DEVELOPMENTS OF 1957

My first very pleasant duty is to give thanks to the British Association for the high honour they have conferred on me by electing me their President for the year 1958. I return thanks most sincerely. To have one's name enrolled on the list of those truly great men of science who have served the British Association during the 130 or so years of its existence is an honour that no one can esteem other than very highly. I would also wish to thank you all for coming to support me on this occasion, the inaugural one of my year of office, and the closing one of my predecessor's. Professor Blackett has completed a distinguished term in which he has guarded most jealously the interests of the Association in a year of great change; and in paying my tribute to him, I am sure you will agree with me that we owe him a very real debt of gratitude for the energy, the thought and the time that he has spent in the devoted service of the Association during the past year. At the end of such a year, I would like, if we could in the few minutes available, briefly to take stock of our British Association outlook and of some of the more active aspects of science—or at least of physical science—active, that is, in the sense that definite progress was recorded in 1957 and that similar progress might well take place during 1958.

THE INTERNATIONAL GEOPHYSICAL YEAR

The year 1957 is strongly associated in the minds of many followers of science with the beginning of the International Geophysical Year, and it is therefore appropriate that I should refer in my opening remarks to the geophysical events which have taken place during the last year.

The advancement of technology has probably never been so clearly demonstrated to the whole world as when the first artificial earth satellite was successfully launched from Russian soil early in October. The appearance of something which could be described as a 'new moon' was a technical achievement which those on this earth with almost negligible claims to literacy could appreciate, and which captured the imagination of the British public to a remarkable extent.

This event, closely followed by the launching of 'Sputnik II', dominates the I.G.Y., and is the first experiment of a type which will undoubtedly add to man's knowledge of space much that our atmosphere has prevented us from discovering before. It should not, however, detract from the other advances which have been made in the study of conditions beyond the outer confines of the atmosphere. Some of these events can at present only be assessed as technical achievements—the American manned balloon which reached a height of twenty miles, the rocket which soared to some 4,000 miles (1), the aluminium pellets (2) some of which are surmised to have been consumed by the sun. So wide is the concept of these

explorations that it will be some time before their results can be properly appraised from a scientific point of view. Already, however, some of the more far-fetched but nevertheless fundamental implications of these experiments are being discussed, for we find eminent students of relativity theory debating in the pages of *Nature* (3) how quickly potential passengers in rocket flights are likely to age during their journeys into space.

There is one science in which the British contribution to the I.G.Y. has been of paramount importance during 1957, and that is radio-astronomy. At Jodrell Bank Professor Lovell has been obtaining the first results from the largest steerable pencil-beam type of radio-telescope in the world; its adaptability was demonstrated by the way in which it was improvised to detect echoes from the Russian satellites, which it very successfully tracked. Recently it has been trained on more distant sources, and its use will undoubtedly add much to our knowledge of interstellar gas (4), radio-stars and solar flares. In this connection, a special tribute is due to the sun, whose contribution to the I.G.Y. has been a vastly great output of sunspot activity.

The other notable British achievement in radio-astronomical research has been the construction of the new interferometers (5) at Cambridge. One of these instruments is intended primarily for the study of radio-stars, and another will be used to investigate continuous radiation from our Galaxy. By these techniques, Mr. Ryle (6) hopes to penetrate further into the outer reaches of the universe than ever before, and thus to throw more light on one of the central controversies of cosmology, whether we live in an 'evolutionary' or 'steady-state' universe.

Against these highlights there is a story of concerted effort in almost every country to find out more about the earth and the sun.

In his Presidential Address to the Association in 1951, H. R. H. the Duke of Edinburgh referred to the development of teamwork which had contributed so much to science during the previous hundred years; seldom has this been so well epitomised as in the geophysical research of 1957. Oceanographers, polar explorers, glaciologists, meterologists, nuclear physicists, seismologists, astronomers, are all combining their contributions to the structure of our knowledge; but we shall not be able to see their work as a whole until 1957 is further behind us, and the meaning of their results has been thoroughly comprehended.

Nuclear and Theoretical Physics

It is probably in the field of nuclear and theoretical physics that the next most significant advances have been made. The award of the Nobel Prize for Physics to Yang and Lee has called public attention to the law of conservation of parity, the universality of which was disproved early last year at the National Bureau of Standards (7) in Washington and at Columbia University. Parity is concerned with the kinematics of groups of fundamental particles, and its conservation in nuclear transformations was assumed until rather more than a year ago. I merely point to the importance of constantly questioning the validity of our beliefs concerning natural phenomena, even when they have sufficient respectability to be called 'laws'. However, I must tread very delicately over these and similar provinces of the specialist.

The discovery of the 102nd element, nobelium, is another announcement made during 1957 (8). It is the first man-made element to be discovered in Europe, and it provides another instance of international teamwork in scientific research, for British, Swedish and American (9) scientists all participated.

The method of preparation was to bombard curium-244 with nuclei of carbon-13, which were accelerated in the 225-cm. cyclotron in Stockholm. Since the half-life of the resulting isotope was only about ten minutes, considerable ingenuity was required to identify it. Those of us who are chemists will be particularly interested

in the properties of any more new elements that are discovered, for we may soon find ourselves exploring a new period in the Periodic Table.

Several significant events have occurred in this country during 1957 which relate to the production of energy. The Harwell nuclear reactors known as 'Pluto' and 'Neptune' have both (10) been started up, and we can expect that the latter will provide much valuable information about the design of reactors for marine propulsion; the need for careful design has been only too strongly underlined by the Windscale accident.

Of more far-reaching significance, however, is the brief announcement that Dr. Thonemann's team at Harwell have apparently succeeded in conducting a controlled thermonuclear fusion in their quartz torus known as 'Zeta' II (11). This type of reaction provides the energy of a hydrogen-bomb explosion, and of the sun, and if it can be made self-sustaining in the laboratory, it is likely to have a major effect on power production later in this century. The energy put into the Harwell apparatus was concentrated by electric and magnetic fields so as to produce a temperature of the order of five million degrees Centigrade (12), and it has been calculated that a ten- to twenty-fold increase would probably be required before nuclear fusion would be self-sustaining. As conducted, the experiment gave detectable quantities of neutrons, which are believed to have been formed as a result of the fusion of some of the deuterium atoms which the apparatus contained. This is a piece of pioneer work the implications of which we can now only see darkly; but in the lifetime of some of us we may see them face to face.

Chemistry

In considering the production of energy, I should also mention the development of chemical rocket fuels. Here the requirement is a stable material which will burn evenly to provide a large amount of energy per unit volume or weight. Of course, the military implications of advances in this field make them more the subject of speculation than of informed comment, but it has been announced that plants are being constructed in the U.S. to produce boron compounds for this purpose. The boron hydrides (13) which, with fluorine, fulfil the requirements of a rocket fuel, are thus gaining importance for reasons other than their enigmatic chemical structure, in which the boron atoms appear to be tetravalent instead of trivalent. It is a matter for conjecture whether the Sputnik rockets were powered by a fuel of this sort.

Before leaving the field of inorganic chemistry, I ought to allude to the production of synthetic diamonds by General Electric in America. Whilst previous claims to have synthesised diamonds have been made, no large industrial undertaking has so successfully devoted research to the project, nor has the development of a commercial process become so far advanced as in 1957. For strategic reasons the U.S. Government has suppressed the details of the process as contained in the covering patent, but it is at least evident that very high pressures of over a million lb/sq. in. are probably used in conjunction with temperatures of the order of 3,000°C. (14). The size of the resulting diamonds is small, yet some are large enough for industrial applications.

In other fields of chemistry, developments during 1957 have been mainly concerned with the continuation of long-term researches, and it would be inappropriate to single out particular discoveries from each developing subject. One such research programme is the study of nucleotides which is proceeding at Cambridge under the direction of Sir Alexander Todd. His work has this year been honourably recognised by the award to him of the Nobel Prize for Chemistry.

Also in the biochemical field, perhaps I may be forgiven for alluding to the progress which Dr. Brian and Mr. Grove and their colleagues have made during the last year within I.C.I. Theirs is one of the few British teams working on the

plant growth-promoting substances gibberellic acid and related compounds. These materials, hitherto only isolated from a fungus, have produced spectacular increases in the height and weight of several plants such as wheat and peas, as well as inducing premature flowering in biennials. Unpublished work in the Akers Research Laboratories has culminated in the isolation of Gibberellin A_1, a derivative of gibberellic acid, from runner-bean seeds; and since the gibberellins and the auxins have been shown to be physiologically interdependent, it now appears that there exists in plants a hormone balance such as is well known to occur in the animal kingdom. Final confirmation of the chemical structures of these new hormones will be awaited with considerable interest.

Conclusion

These are a few items on the line of active development and it will be interesting to see how they progress during 1958. The list is far from being exhaustive, but it is, I believe, enough to show that our science is very much alive and that it will continue to penetrate into the daily lives of our peoples.

I have not the least doubt that this wealth of exciting achievement in 1957 will enable us first of all to continue the task of extending the Association's influence for the advancement of science throughout widening circles of British people and, more particularly, will assure the success of its new scheme for presenting science to the younger generation.

None of us, I feel, need any convincing that in the present setting the Association has one of its most important tasks in getting more and more people of these islands to realise the vital importance that science is to them. That is the broad task to which our Council has once again affirmed its resolve and for which our support is required and indeed is demanded.

I have very briefly sketched what to me is a wealth of exciting scientific achievement and thought, and I feel that, properly handled, such achievements can be made to compel the interest of the young people of Britain to the furtherance of the scientific ideal. To work for this end the Council of our Association is initiating two steps which will be integrated with each other, and both should proceed simultaneously by methods which our secretarial organisation will in due course indicate. They will help to develop our inter-meeting activities. The two steps which are proposed are, first, Area Committees and then a panel of speakers. Area Committees would seem to be essential for the whole country to make local arrangements for lectures, exhibitions and so on. The effectiveness of such activities will very largely depend on the effectiveness of the Area Committees. And so I express the hope that keen members of the British Association will play an active part in running them. The second piece of organisation is the formation of a panel of lecturers. We think such a panel must be large—more than a hundred—and its essential characteristic is that its members should be able to put across science to general audiences and to young people. The gift of interpretation is not given in equal measure to all of us, but to those who have it in good measure, I appeal to join the panel and to play a part in the interpretation of new discoveries. Given some basic understanding, experience tells us that the capacity to speak in simple terms is an art that can be cultivated, and so judicious cultivation may well be like the quality of mercy twice blessed—to those who give not less than to those who receive. I hope the Association will receive whole-hearted support in this vital task.

I have briefly indicated some of the matters that are much in mind as I take up the serious task you have assigned to me—to be your President for 1958. I trust that by diligence and interest and attention to business together we may make the year worthy to rank with any of its predecessors as one wherein the minds of British people will to an increasing degree respond to the opportunities given to them by the Advancement of Science.

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BILINGUALISM

SECTIONS J (Psychology) and L (Education) devoted the morning of September 9, 1957, to a joint discussion of the educational, psychological and administrative problems of bilingualism. The Rev. Prof. E. F. O'Doherty, Professor of Logic and Psychology in University College, Dublin, dealt with the educational aspects of bilingualism. Sir Ben Bowen Thomas, Permanent Secretary in the Ministry of Education, contributed a paper on 'an administrator's approach to the implementation of a bilingual educational policy'. The session ended with a contribution from Mr. John R. Morrison, Lecturer in Education, University College, Aberystwyth, entitled 'Bilingualism: some psychological aspects'. Mr. Morrison's paper gave an account of some features of psychological interest in Welsh–English and Gaelic–English bilingualism among school children in Wales and Scotland.

The papers by Prof. O'Doherty and Mr. Morrison are printed below.

BILINGUALISM: EDUCATIONAL ASPECTS

By The Rev. Prof. E. F. O'Doherty

The problem of bilingualism has occupied the attention of psychologists and educationalists for upwards of half a century (Mocaer's study was published in 1905: *Enseignment bilingue au Pays de Galles*). Since that time more than a hundred studies of the problem from various aspects have been published. One of the best bibliographies on this topic is available in the Report of the Central Advisory Council for Education (Wales), entitled *The Place of Welsh and English in the Schools of Wales* (H.M.S.O., 1953). The few papers not included in this list do not add significantly to our knowledge of the problem.

But in spite of the enormous amount of the material available, and the devotion and goodwill of the researchers in this field, it is one of the most difficult psychological and educational problems to discuss dispassionately. It is easy to see why this is so. The theoretical and experimental issues can be discussed and studied calmly from a purely psychological point of view, but the reality-situation is part of a wider problem involving political, national, economic and sociological considerations, with which the psychologist as such is not concerned, but from which in practice he prescinds at his peril.

The very nature of language itself often eludes the psychologist and confuses the issue for the educationalist. It is without doubt the most important problem for the contemporary philosopher. If he could solve it, he would have the key to most of the other problems which bother him. For language has often been treated by philosophers as well as by politicians as if it were an object, a thing-in-itself, or even an end-in-itself, and its essential function confused with its incidental uses: to inculcate a particular *nazionsgeist*, to give the *entrée* to a particular culture, even in some vague sort of way, 'to train the mind'—this latter idea being based on some ill-considered assumptions about the 'transfer of training'.

A word or two about language might help a lot before we get down to the problem of two languages. For language, whatever else might be said about it, is at least this: it is a symbol system whose function is interpersonal communication. A symbol is a sign, but a rather special sort of sign. Signs are of two kinds: natural and conventional. A natural sign is something which is linked causally with that which it signifies, as for instance smoke is a sign of fire, or dark clouds are a sign of rain. But the poet can use dark clouds as a sign of sorrow, and we are all agreed that a red flag is a sign of danger. Such signs are conventional: they might have been

otherwise, whereas natural signs are not matters of sheer convention. A conventional sign is usually also a symbol. The specific character of being a symbol lies in the fact that the thing signified is of a different order of reality from the sign itself. It is in this sense that a national flag (which is a conventional sign) is also a symbol.

The cry of an animal, or even such human sounds as laughter, sobbing, or the cry of pain usually written *ouch!* are all natural signs: they are causally linked with the experience which they signify, and they are not just matters of convention. Thus, while animals can communicate with each other and with man, the signs they use are not language. For language is a system of symbols which might have been other than they are, but within a given system they are subject to the conventions of the group. Thus the same sound will have different significance depending on the conventions of the group which uses it. Compare the sound *mare*, *mere*, *meer* in England, France and Germany.

Animal cries involve *utterance*, and sometimes (if they are heard and responded to) *evocation*. But language involves in addition the concept of *reference*. And it is here that the symbolic character of language emerges. For the sound uttered in language is not the name of itself, nor does it signify an inner condition of the one who utters it (though it may be used for this purpose, as when the poet says, 'I fall upon the thorns of life, I bleed!'), but rather its primary reference is to something other than itself, and of a different order of reality. Thus *dog* refers to a particular kind of creature, while the sound itself is simply the physical vibration of an elastic medium with a particular frequency, wavelength and intensity.

It is a curious fact about symbols or conventional signs, that anything can be a symbol of anything else. Analysts are accustomed to this wealth of symbolic possibility—even to the notion of ambivalence, or more simply, the notion that the same symbol can symbolise contradictory things. And for the psychology of language, it means that there is no reason other than historical accident why one sound rather than another should signify a particular thing. There are no psychological categories of better or worse whereby we can judge between languages. Differences of grammatical structure or of complexity of word-building between different languages may cause difficulties for the adult or adolescent learner, but it is interesting to reflect that even the most complicated languages from this point of view are mastered with ease by the children whose languages they are.

Finally, for the preliminary consideration of language as such, there is the vital point to be made that language is primarily a device for interpersonal communication. Private inner speech is a very secondary use of language, while 'talking to oneself' can be pathological. Attempts have been made of course to identify 'thought' with internal linguistic behaviour—which is simply a distortion of language itself in the interest of a particular point of view in psychology and philosophy: but this is done in order to avoid having to accept the consequences of the view of language I have been putting forward—a view which entails the idea that language is a conventional interpersonal symbol system, whose primary reference is to things, and whose secondary reference is to thoughts. Thoughts are different from, and of a different order of reality from, the sounds which symbolise them.

The individual words of a language are all symbols. But it is important to note that the language itself as a whole can also be a symbol, but a symbol of a different kind. It can become a symbol of independence, or of nationality, or of culture, or of lack of culture. To know Latin or Greek was a symbol of culture, to speak French well was and is a symbol of culture, to speak only a dialect is often a symbol of lack of culture. Language as a symbol of independence or nationality is a valuable thing. But there is a danger about all symbols, but especially about social symbols, which is vital to an understanding of human society. It is the danger (of which the examples are legion) that the symbol may itself take precedence over the

thing symbolised. This is what happens in the idiosyncratic use of individual words by the schizophrenic. Its analogue in society is the elevation of the symbol above other social values.

I would like to stress the point that language is primarily and above all a device for interpersonal communication. This is the social aspect of language, and while social psychology is still in its infancy, it would be extremely rash for the psychologist or educationalist to neglect it.

For the very first society into which the child is born is the natural unit we call the family. The child first of all manifests its wants and needs and urges through cries which are not language. But the inadequacy of this means of communication is very soon evident. Soon the child becomes a party to the conventions of his group. The sounds which he now begins to utter, and which he refines and perfects through babbling games and exercises, lead at a rate of progress unparalleled in any other acquired skill, to his speaking a language. Now this language which he speaks is his 'vernacular', his *langue maternelle*, his 'mother tongue' (because it is his 'mother's tongue'). It may not be his ancestral language. It may have a history of injustice, tyranny, bloodshed, or worse behind it. It may have political, economic or social antecedents or consequents. But psychologically and educationally it is the child's mother tongue. In most countries and societies, it would also be called his 'native language'. But for the benefit of our visitors, I should explain that the words 'native language' or 'mother tongue' are conventionally used here by many of our people to refer to the ancestral language rather than to the language of the primary society into which the child is born. This is a simple fact of linguistic usage which has had far-reaching effects on the thinking of many of our people with regard to the problem of bilingualism. For in nearly all the studies available on the topic, and in nearly all countries where there is a bilingual problem, investigators have consistently recommended that children should be taught their native language, and other subjects through its medium. We shall look into this in a moment. The point is that their recommendations were psychologically and pedagogically in favour of the language which was the normal means of social intercourse of the child. But they called this language the child's native language, his mother tongue, and it very often was also his ancestral language. But here, owing to the different linguistic convention, these recommendations have often been interpreted in a contradictory opposite sense: that is to say, the child's normal means of social intercourse has been by-passed in favour of what for many (though not for all) is the ancestral language. I do not want to labour the point too much but it is vital for the understanding of the problem here.

I would like to suggest that bilingualism should not be confused with pseudo-bilingualism. I am going to use pseudo-bilingualism as a technical term to describe the position of a child or adult who has achieved *mastery of one means of social intercourse proportionate to his age and social group*, and who has in addition acquired some knowledge of another means of communication *without mastering it*, and such that the second language is not an automatic medium of social intercourse. That is to say it does not achieve the primary purpose of language. Thus there will be few bilinguals compared to the pseudo-bilinguals in the population. I think there can be no doubt that genuine bilingualism is an asset. Thus the child who has mastered French and English is to that extent at least better than the child whose only language is English. At this point however I would remind you of the confusion I spoke of earlier in this paper: the confusion between the essential function of language and its incidental uses. Since language is not a thing-in-itself nor an end-in-itself, the mere possession of two languages in no sense ensures any intellectual advantage over the monoglot, nor does it necessarily involve any other advantage of any kind. The value, like the life, of a language depends exclusively on the use made of it.

There are many pseudo-bilinguals in the population. The pseudo-bilingual is the real problem, since very often he fails to master either language, while the bilingual by definition has mastered both. This is the complicating factor which makes it so difficult for policy makers to assess properly the value of many of the hundred-odd studies available under the general title of Bilingualism.

There is no doubt that the 'verbal factor' plays a part in determining the result of an intelligence test, and militates against the valid assessment of the intelligence of a bilingual or pseudo-bilingual child. The evidence is overwhelming, and is best shown, as is well-known, by a comparison between the results obtained on the same group of children using both a verbal and a non-verbal test.[1] (See Colvin and Allen, Pintner, Wright and Manuel and others.) But there are two observations to be made here. The first is that the verbal factor plays a most important part in the whole of life, in all social intercourse, and in all normal means of education. If therefore the bilingual child is consistently behind the monoglot (by a factor of up to one and a half years in mental age by the end of adolescence) in his performance on intelligence tests, and if this is so because of the 'verbal factor' (which in fact is usually minimised in a good test), it is not really any help to say that the child's innate intelligence is the same as his monoglot brother's. For if the verbal factor impairs his performance in a test, it will *a fortiori* impair his performance in life, where almost everything he does will depend on language.

The second point is a rather theoretical one, but one which because it has not always been adverted to, has complicated the issue considerably. An intelligence test is intended to test the innate ability of the child, not his acquired skills. Nevertheless, an intelligence test cannot help being also to some extent an attainment test (e.g. the 'verbal factor'). This is why the scores of bilinguals and monoglots correlate more highly on performance tests than on tests of the verbal kind. But whereas this evidence is appealed to, apparently to show that bilingualism has no effect on intelligence when only intelligence is involved, it is forgotten that this is not the result of experiment and investigation, but is a condition antecedent to the construction of the tests themselves. In other words there is a neat vicious circle in the reasoning.

Very often the evidence of the investigators into the effects of bilingualism is ignored by those who are involved in the policy side of education. It appears that this happens for many reasons, but in general there appear to be two outstanding reasons for it. The first goes something like this: even if all these findings are true, it is argued, they are nevertheless irrelevant, because the issue is decided on grounds other than the intelligence or welfare of the children: on grounds of politics, or culture, or tradition. With this argument one can disagree violently, but a scientific meeting is hardly the place to do so. But it is evident that if this is the argument, it is bad psychology, bad educational philosophy, and bad educational practice.

The other reason advanced for ignoring the findings of investigators usually takes the form of an appeal to one's own experience. Instances are cited of a particular family, or a particular child or a particular school, where bilingualism had has no disastrous effects, or may even have been an advantage. There are many points to bear in mind in this connection: it is not good to base a general policy on the evidence of the exception. The children singled out as examples of the benefits of bilingualism are usually already a selected population. In many cases, they are genuine bilinguals, in the sense defined above: they have two vernaculars. And the

[1] A relatively mild language handicap (such as is met with in the case of the children of immigrants to U.S.A., who speak their own language at home but English at school) 'may have a pronounced effect upon intelligence test scores' and this has been repeatedly demonstrated (Anastasi, in *Fields of Psychology*, 1952, reprint of the 2nd ed.). On such predominantly verbal tests as the Stanford Binet, National Intelligence Test, Otis Group Test, 'an unmistakable tendency is found for those children who speak exclusively English at home to excel the bilinguals'.

schools which sometimes produce spectacular results are actually monoglot schools operating on a select population. By that I mean that the medium of communication between teacher and pupil is also the spoken language of the pupil in the school, at play, and very often also at home. Evidence from such schools is not at all the kind of evidence on which a policy for pseudo-bilingual school children representing a normal cross-section of the population should be based. For such children, the evidence is overwhelming that a pseudo-bilingualism in school years produces a retardation of anything up to a year and a half by mid-adolescence. It is true that many of these children will catch up again later. By why should they be retarded first? The question is especially relevant since the great majority of them never become genuine bilinguals at any point.

On a different psychological plane for a moment, let me give you the results of clinical observations over twelve years. The emotional life of a large proportion of our children is disturbed by the pseudo-bilingual situation in which many of their early years are spent. This disturbance is both conscious and unconscious. The conscious disturbance takes the form of unhappiness and a dislike for school. But it is the unconscious disturbance which is of more interest to the psychologist. When a child has discovered the magic of words, the fact that he can manipulate symbols which produce results, there occurs one of the great bursts of personality development. But the child who suddenly discovers that his magic is no longer efficacious, who discovers in other words, a total or partial breakdown in communication, may suffer (and very often does suffer) a loss of orientation and self-confidence which may result in a temporary suspension of all development, personality and linguistic. But more to the point perhaps is the long-range effect. This early (and often prolonged) breakdown in social assimilation emerges later in life as a revolt. It is not necessarily an anti-social revolt in a generalised sense, but very often indeed it is a revolt against this specific society or against the parents or teachers with whom the breakdown in communication is most closely associated. Or to put it more simply, the initial failure of the child because of the language-barrier to identify with the group, or to achieve what the Americans call 'belongingness' is certainly a contributory cause of emigration from this country.

Let me try to state in a few sentences the difference between our situation and that of Wales, the Scottish Highlands, the Belgian Walloons, Spanish Catalan-speaking children, Breton-speaking children in France, or almost any other example that comes to mind. In all these cases the plea for bilingualism rests on the child's welfare and on sound psychological principles: the sort of principle enshrined in the Belgian constitution, Article 20: 'Dans toutes les écoles communales, adoptées ou adoptables, la langue maternelle des enfants est la langue vehiculaire aux divers degrés de l'enseignement.' In terms of this very reasonable principle, our Irish-speaking children should be taught through Irish, because Irish is their vernacular. But if the principle is sound it should also mean that children whose vernacular is English should have English as their *langue vehiculaire* at school. It would appear from the *Report of the Council of Education*, published 1955, that the members of the Council were alive to the psychological issues involved (see especially paragraphs 214 and 239). Nevertheless, the majority report underwrites in general the policy established as far back as 1922, repeated in 1926, and again in 1931, summed up best perhaps in the sentence: 'The aim of the programme (for primary schools) is to secure the full use of Irish as the teaching medium in all schools as soon as possible' (cir. 11/31 entitled, 'To Managers, Teachers and Inspectors on Teaching through the Medium of Irish'). It is true that there are certain saving clauses in the Departmental Regulations. It is stated for instance (cir. 11/31): 'Where a teacher is competent to teach through Irish and where the children can assimilate the instruction so given, the teacher should endeavour to extend the use of Irish as a medium of instruction as far as possible. When these

conditions do not exist, such teaching through Irish is not obligatory.' But the Revised Programme for Infants (1948) explicitly aims at 'giving to young children, *from English-speaking homes*,[1] a vernacular power over Irish at an age when they are most adaptable and imitative, and when their vocal organs are plastic. Where the teachers are sufficiently qualified the aim should be to reach a stage as early as possible at which *Irish can be used as the sole language of the Infant School.*'[1] No real change is suggested in the 1955 Report, in spite of the fact that the members realise (par. 214) that 'much criticism has been directed at the position given to Irish in Infant classes, chiefly on the grounds that at this stage, in particular, the work should be done through the medium of the home language'.

In a sentence, what it comes to is this: our present pseudo-bilingual policy is based on emotional, political and historical factors, to the neglect of pedagogical, psychological, and social considerations.

BILINGUALISM: SOME PSYCHOLOGICAL ASPECTS

By J. R. Morrison

This paper simply constitutes an illustration of the fact that a great deal more of solid, large-scale research, and of controlled experimentation in schools, is needed before any valid psychological conclusions can be reached about bilingualism.

Although the term *bilingualism* occurs in the title of my talk I am going to use it very little. It is too abstract, variable, and vague in meaning to be profitably considered in twenty-five minutes; much longer would be needed to clarify it and to classify its many varieties. I shall speak instead of the *bilingual child*, and confine myself mainly to the kinds of bilingual child that are to be found in Wales and Scotland, since these are the only ones with whom I have first-hand acquaintance.

No doubt the 'ideal' bilingual child is one whose knowledge of, and familiarity with, each of his two languages are equal in duration and extent and whose attitude to each of them is identical; he might be called *equibilingual.* Such children, however, seem to be relatively few in the Gaelic-speaking and Welsh-speaking areas. Much commoner than the equibilingual child is the child whose first language is Gaelic or Welsh and whose knowledge of English is largely or wholly confined to what he has learned at school. Some such children ultimately acquire a 'second-language' vocabulary exceeding their 'mother-tongue' vocabulary. Clearly, all sorts of factors will make their contribution to the final balance: the home background, the social environment, the policy of the local education authority or school, the child's own intelligence and verbal capacity, the length of time he remains at school, and his emotional attitudes, *conscious and unconscious*, to the two languages.

Then there is the English-speaking child who learns some Welsh at school. This type is by no means uncommon in Wales, and is becoming commoner. His attitude to his second language, however, is not wholly favourable in all cases, as we shall see later.

The corresponding type of child in Scotland—the child who learns Gaelic at school—is far fewer in number, but is increasing, though the percentage in the total population is still statistically negligible. But the *attitude* of these few is wholly favourable; their bilingual status, such as it is, is a purely voluntary one.

Knowledge of the actual vocabulary of bilingual children in each of their two languages at each year of age ought to be made available by research. It would have to be such a large-scale research that only a national body could be expected to sponsor and conduct it. Similarly, knowledge of the sentence-structures and idioms which such children actually use in each language is desirable. A small-scale research on these lines is being carried out at present in one area of Wales by a research student; but again, what is really needed is a nation-wide survey.

[1] My italics.

Most of the research that has hitherto been done in this field has been concerned with comparisons between the scores made by children aged 10 to 12 in certain kinds of tests, for example, intelligence tests (both verbal and non-verbal), attainment tests in each of their two languages, and, more recently, some form of questionnaire designed to estimate the relative proportion of each language occurring in the linguistic environment or 'background' of the child. The whole situation is complicated by the intrusion of two further factors: the urban-rural factor and the socio-economic status of the parents. All these factors exert their influence on the children's scores in both intelligence and attainment tests, while of course the quality of the teaching in each school also affects the attainment considerably.

However, four results do appear to be fairly validly established.

(1) Bilingual children, on the average, tend to score rather less than monoglots of the same age in existing intelligence tests. (These tests were, however, designed for monoglots, not for bilinguals.)

(2) If the intelligence tests are *non-verbal*, the retardation of the bilinguals is either greatly reduced or else vanishes altogether, depending partly on the incidence of the urban-rural and socio-economic factors.

(3) It does not seem to matter so much as one might expect whether non-verbal intelligence tests or mechanical arithmetic tests are administered in the child's first language or second language. As an illustration of this I may mention a case of a Gaelic-speaking boy of eleven who had just done Raven's Progressive Matrices test, and whom I asked whether he had done it thinking in Gaelic or in English. The reply was, 'Please, sir, I tried it in the English first, then I tried in the Gaelic to see would it be easier; but it wasn't, so I went back to the English'.

(4) There is a negative correlation between the amount of the first language (Gaelic or Welsh as the case may be) in the child's linguistic background, on the one hand, and his scores in both kinds of intelligence tests (verbal and non-verbal), and in English attainment tests, on the other hand. This negative correlation is *least* in the case of *non-verbal* tests. In Wales there is, however, as one would naturally expect, a positive correlation between the amount of Welsh in the child's linguistic background and his attainment in Welsh. But in the Western Isles of Scotland I found in 1941 a negative correlation even between the amount of Gaelic in the linguistic background and the score in a Gaelic verbal intelligence test! My guess is that this was due to inadequate time being given to the teaching of Gaelic reading in some of the schools. The more Gaelic the background of the district, the stronger the teacher's temptation to concentrate on imparting an adequate knowledge of English; nevertheless, the results of attainment tests in English showed that this tended to be a losing battle, i.e. there was a *larger* negative correlation between Gaelic background and English attainment than between Gaelic background and Gaelic attainment.

Even the so-called 'non-verbal' tests do contain a small residue of 'verbal factor', as is shown by factorial analysis. When such an analysis was performed on the tests just cited, and the axes rotated by Thurstone's method into what appeared to be the best psychological position with respect to the intelligence and attainment tests only, the linguistic background questionnaire fell exactly upon the verbal-factor axis. This suggests that the linguistic background was in fact quite independent of what the factor-analyst delights to call 'pure g'—a kind of 'Platonic form' of what the more terrestrial sort of psychologist is content to designate as 'general intelligence'.

An interesting minor result, confirmed in both Scotland and Wales, is that the only well-known intelligence test *without a time-limit*, namely, Raven's Matrices, appears to be the most suitable for bilingual children, who show less retardation as compared with monoglots in this test than in any other intelligence test. This test is also less influenced by the linguistic background than any other so far tried.

This is probably due more to the absence of a time-limit than to anything else. It stands to reason that the bilingual child, having to make an act of choice between his two languages, and perhaps trying both like the boy I quoted, tends to be at least *slightly* slower at thinking than the monoglot, other things being equal.

Space compels me to leave the cognitive aspect there and say something about the affective aspect. Two main lines of research have been tried here: the investigation of reaction-times and responses to stimulus-words in the two languages, and the estimation of attitudes.

In 1930 Dr. H. A. Saer, of Aberystwyth, gave a word-association test of Jung's type to 50 girls at a secondary school in South Wales, using, however, not Jung's words but a specially-chosen list of 50 words which should have entered affectively into a child's life by the age of three (e.g. mother, baby; cat, dog; sun, moon, dark; table, chair, bed; cup, spoon; noise, laugh, cry, fall, kiss; God, good, clean, dirty). The 50 words were given in random order, in both English and Welsh, and the response-word and time of response were noted. (By the way, this method is of respectable antiquity; it was as long ago as 1877 that J. M. Cattell in the U.S.A. measured the time required for an English stimulus-word to elicit the equivalent word in German, and found the time 'surprisingly long' for English-speaking subjects familiar with German.) To return to Dr. Saer's experiment: if the time and nature of the response agree for a pair of words, one English and one Welsh, the child might perhaps be regarded as *affectively equibilingual* in respect of that pair of words.

The most interesting result was as follows. With many of the word-pairs, i.e. a word in English and its equivalent in Welsh, responses were very similar throughout the group of girls, both in time and nature; but with certain other word-pairs, notably those meaning God, quiet, noise, blood, nasty, sister, play, sing, dirty, wicked, and clean, the tendency was to show a much longer reaction-time in the one language than in the other and to give differing individual responses. The emotional significance of such words is evidently far greater in the mother-tongue than in the second language; it is thus very difficult, if not impossible, to become really equibilingual in respect of these words, and no doubt of others with similar meanings and early associations. (R. B. Cattell has shown that it is *normal* for a monoglot child to give long reaction-times to many of the above words, in English.)

In 1941 I myself gave a similar test, using Cattell's child-guidance clinic word-list, to Gaelic-speaking children, both boys and girls, in one of the Western Isles of Scotland, and obtained very similar results. It was notable that words giving long reaction-times or 'queer' responses—what Jung would call 'complex-indicators'—in Gaelic were mainly words connected with the *home*, but in English words connected with the *school*, where English is the medium of instruction. Thus it seems to be quite usual to possess a repressed complex with regard to the word 'salach' in Gaelic but none with regard to the corresponding word 'dirty' in English, and to have a complex about 'lazy' in English but not about 'leisg' in Gaelic! And so for several such pairs.

As regards attitudes, the only British research I know of is the one by W. R. Jones, of Bangor, in 1948. Jones constructed a scale for measuring the attitudes of children towards Welsh as a second language in school. He then gave the scale to 129 boys and girls, aged 11 to 13, in a secondary modern school in an industrial area in South Wales. He found that in the first-year forms the average attitude was slightly favourable towards Welsh, but that this declined during the second year and by the third had become slightly unfavourable. Girls had, on the whole, a more favourable attitude to Welsh than boys, and children from Welsh-speaking homes were more favourable than those from English-speaking homes; also, children from homes where the mother only was Welsh-speaking were more favourable towards Welsh than those from homes where the father only was Welsh-speaking!

Finally, I would like to mention briefly two recent contributions from Canada (both, as it happens, from McGill University).

In the first, Dr. W. E. Lambert has elaborated the reaction-time method, using specially-devised electrical apparatus. His subjects were French-English bilingual students and graduates. If a subject's reaction-time to one language is much quicker than to the other, Lambert calls him *dominant* in that language; but if the reaction-times are about equal, he calls him *balanced*. The reaction-time measure of 'dominance' was found to correlate 0·82 with the subject's 'active verbal output' in his dominant language. Further tests showed that 'dominants' could read and associate quicker in their dominant language than in the other, while 'balanceds' could read and associate equally quickly (or equally slowly!) in both languages. There was, however, a most intriguing complication with regard to translating ability. Half of the dominants who were quicker at reading French were quicker at translating *into* French, and the other half at translating *out of* French; and similarly with those faster at reading English. This peculiar difference is under further investigation.

It was also found that those who had learned both their languages *at home* tended to have similar attitudes to both, while those who had learned one at home and the other *at school* tended to have different attitudes to the same object or concept when named in the different languages—confirming and extending what Dr. Saer and I found in Wales and Scotland.

In the other contribution from McGill, Dr. Wilder Penfield, an eurologist, has adduced physiological reasons why children, if they are to become efficient bilinguals, should be taught their second language (and even their third) in infant and primary school. According to him, the speech areas of the brain are at their maximum sensitivity from nursery-school age up to 8 or 10—no more. After that age these areas lose their plasticity and become progressively less receptive, more rigid. He goes so far as to state that after the age of 14 the brain, as regards the learning of new speech, is 'soon senescent'. It is clear that this, if substantiated, ought to have the greatest influence, not only on our bilingual policy, but on our teaching of second languages in schools in monoglot areas. 'I know quite well', said Penfield to the American Academy of Arts and Sciences at Boston in 1953, 'that educators are not in the habit of asking for physiological consultation in the planning of their curricula, and that the neurosurgeon who offers advice unasked may well be placing his head in the lion's mouth'. Perhaps this Association might care, at some future meeting, to invite Dr. Penfield to place his head, for a change, in the 'British Ass.'s' mouth.

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RURAL CHANGE IN AN IRISH TOWNLAND, 1890–1955[1]

by

R. H. BUCHANAN

IN RECENT years, an increasing number of geographers have turned their attention to the changing features of the rural landscape as a significant field of study. A general criticism of such studies is that some students have tended towards a largely descriptive analysis of specific landscape features; they have discussed, for example, changes in field and settlement patterns as though these were separate entities, and not as related parts of a complex whole. These studies lack an adequate synthesis, since only the changes which are apparent in the landscape are discussed, and no attempt is made to relate these to changes in the pattern and organisation of rural life and work. Yet the cultural landscape is the external manifestation of the culture which created it; and changes in that landscape are therefore but one expression of cultural change, to be interpreted only in terms of changes in the total culture.

In this paper an attempt is made to describe changes in the pattern of fields and farms in an Irish townland during the past sixty years; and by analysing these changes to show that they are reflections of fundamental change in economic and social life.

The subject of this study is the townland of Sheeplands,[2] which is situated on the south-east coast of Co. Down, some thirty miles from Belfast. The highest land fringes the Irish Sea, and drops to the sea in cliffs which vary in height between fifty and one hundred feet. It is a treacherous coast, deeply notched with narrow cliffs and gulleys, and bounded by jagged offshore reefs. Only in two places is the rocky foreshore interrupted by shingle and sandy beaches, which provided a precarious refuge for the fishing yawls of former days.

From the whin-covered 'knowes' of the coastal rim the land slopes gently inland, its undulating surface drained by a solitary stream which flows from a boggy hollow in the heart of the townland to breach the cliffs at Sheeplands Harbour. The land is fertile, for a moraine lies behind the coast, giving rise to a lush green landscape which in autumn is relieved by the brown tints of the dying bracken and the golden tips of the furze, which grow in profusion among the rocky outcrops along the coast.

Settlement in the townland (Fig. 1) is composed of two fundamentally different elements, both reflecting profound social differences in their respective historical development. On the one hand are the dispersed farmsteads, typical of the inland parts; on the other, the nucleated clusters of the north and east.

In the south and west, where the dispersed farmsteads are found, the landscape is chequered with an orderly pattern of squared fields, 3 or 4 acres in size. The farmsteads, each placed centrally in its holding, are relatively large, and have generally an air of prosperity.

The layout of these farms gives some indication of the local agricultural economy, and also of the standard of living of the farmers, whose holdings today average 40

[1] Address delivered to Section E (Geography) on September 9, 1957, at the Dublin Meeting of the British Association.

[2] The townland is the smallest territorial unit in Ireland. Officially, Sheeplands is composed of two townlands: Sheepland More (632 acres) and Sheepland Beg (175 acres). In local usage this division has little significance and in this paper Sheeplands will be referred to as if it were a single townland.

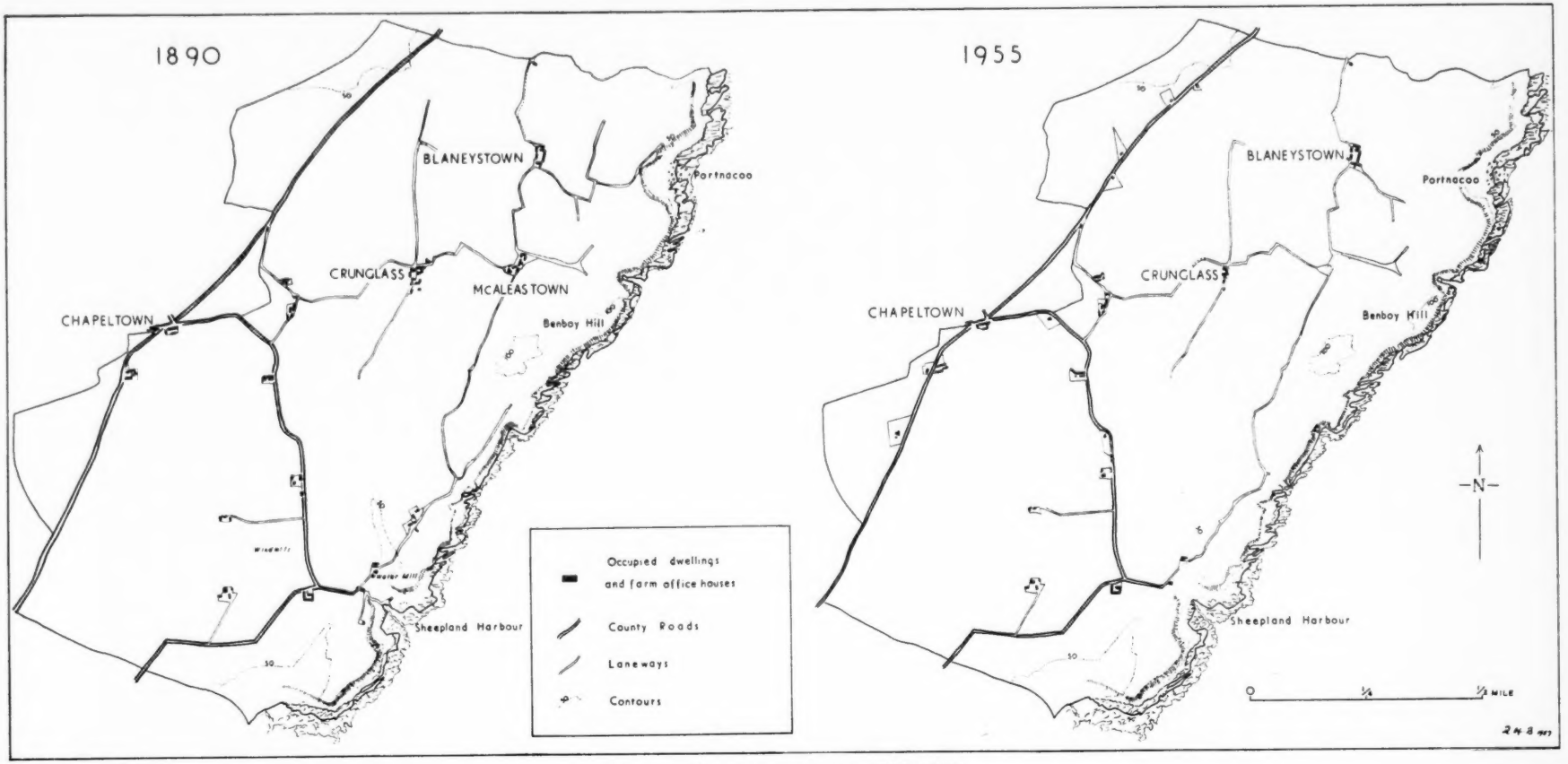

Fig. 1.—*Changes in settlement,* 1890–1955.

acres. The largest of the outbuildings, which are usually grouped around the dwelling to form an enclosed yard, is the barn and granary, usually the only two-storied building on the farm. Formerly the stable was next in importance, for many of these farms kept up to four working horses, but in all the compact farms the tractor has now taken their place. The byre is much less prominent, for dairying has never been important here; instead, while grain growing was formerly of much greater significance, the main emphasis in the economy today is on the raising of lambs and young store cattle. Cart-sheds and other storage houses make up the

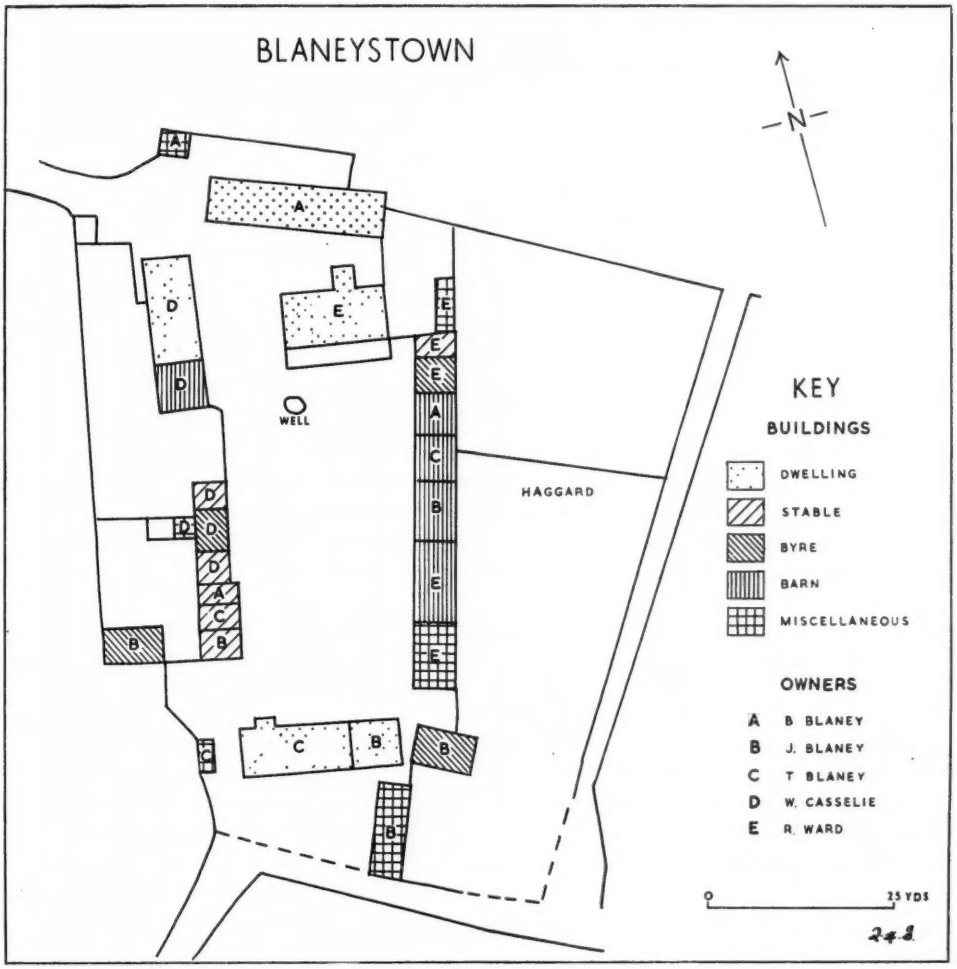

Fig. 2a.—*Blaneystown*, 1890.

rest of the outbuildings, together with several substantially built pig-sties—a relic of the days when the pig was the 'gentleman who paid the rent'.

These dispersed farms are today relatively prosperous, the neat buildings and compact holdings conveying a feeling of stability which is in fact backed by a long tradition, for they have remained virtually unchanged for over a century and a half. Most have for generations been owned and worked by the same Protestant families, descendants of English and Scottish immigrants who settled in south-east Co. Down during the early seventeenth century. The religious factor is important, for the rest of the population is Roman Catholic; the two-fold division of the cultural landscape is thus an equally important social division.

A second element in the dispersed pattern is formed by the dwellings of a slightly lower social group: the half-dozen labourers' cottages built by the local rural district council forty years ago. Significantly these form a ribbon of settlement along the main road, along which the landless labourer must travel, either to his work or to draw 'the dole' at the nearest employment exchange.

Fundamentally different from the dispersed farmsteads are the nucleated farm clusters or clachans, known locally as 'the towns', which occupy the rest of the townland. The landscape here is different. Fields are smaller, sometimes less than

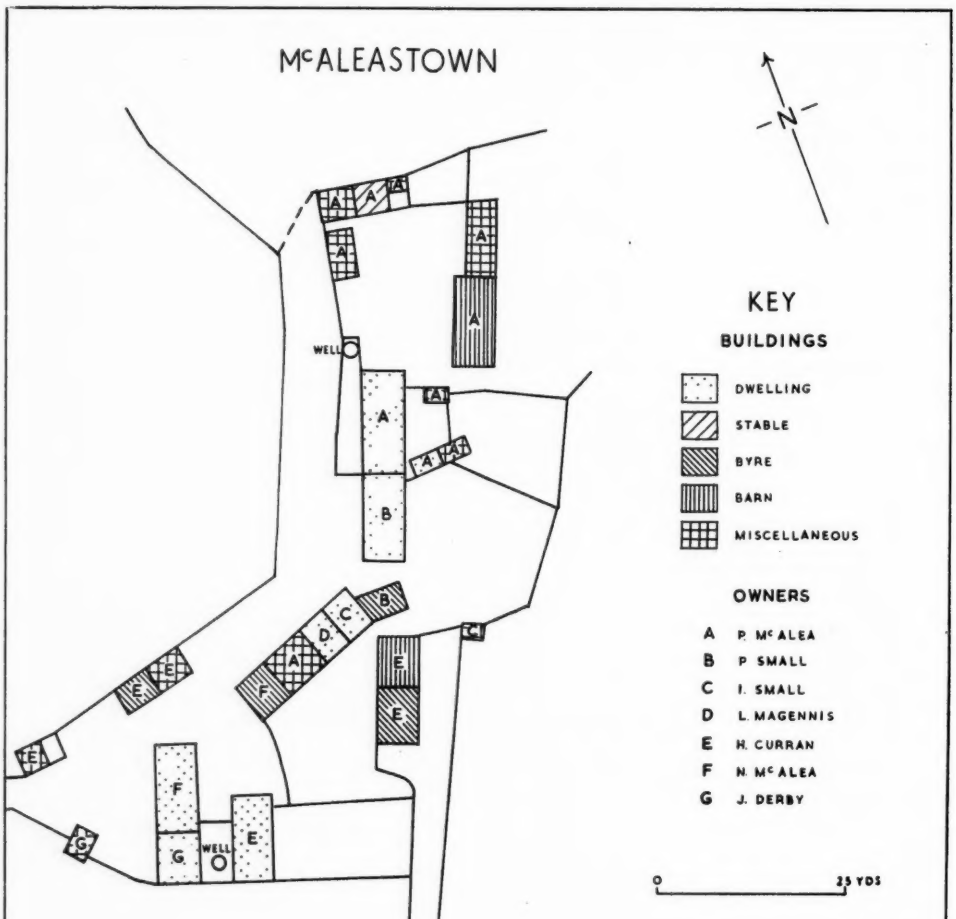

Fig. 2b.—*McAleastown*, 1890.

an acre in size, and farms average less than 25 acres. The fields of a single holding are widely scattered, sometimes in as many as eight detached lots, quite unlike the compact holdings of the south and west (Fig. 3). This pattern of field and farmstead reflects a social and agricultural organisation which was quite different from that in the rest of the townland. Here the rundale system—the agricultural system whose basis was communal holding of land and communal labour by closely related families—persisted until the middle of the last century. Fig. 2 shows the layout and functions of the buildings in two of the clachans, Blaneystown and McAleastown, as they were sixty years ago. In Blaneystown, the five dwelling-houses faced each other across a broad, partly cobbled square, the enclosed quadrangle being

completed by ranges of outbuildings to east and west. Those to the west were mainly stables, those to the east barns; and each of the families had its building in the appropriate block. To the east lay the common haggard in which each man had his own stands for building stacks of grain.

McAleastown, a now deserted cluster, is completely different in plan, its houses strung out in a long straggling line along 'the street'. At the northern end of the cluster was the largest farm, its compact layout contrasting with the haphazard arrangement of the rest of the town. It gives an impression of social isolation which is more apparent than real, for this family was connected by blood-ties with other families in the town, and the obligations of social life did not recognise the prestige which greater wealth might be expected to confer.

The arrangement of dwellings and outbuildings of the other six families in the town illustrates the 'through-other' layout of the settlement. These families had little land: the largest holding was 13½ acres, the smallest, 5 acres. Most of the farms had a byre and henhouse, but only the largest had a barn and stable. Thus general poverty and a low level of subsistence were characteristic of 'the town'.

Today the character of the nucleated settlements has changed completely. Sixty years ago almost half the total population of the townland lived in them; today Crunglass has only two houses inhabited, and the dwellings of the cottier fishermen along the shore are in ruins. McAleastown is completely deserted and, of the three, only Blaneystown retains anything of its original character, although it too has an air of neglect and decay.

This then is the landscape expression of rural change. The ruined cabins along the shore, the deserted towns with their roofless dwellings all form a marked contrast with the prosperous-looking compact farms of the south and west. These changes in the pattern of settlement—the decline of the towns and the stability of the single farmsteads—suggest a profound social change which has taken place in the community during the past sixty years. This is further reflected by the erection of the labourers' cottages, for these dwellings are the only new houses built during the period.

In the landscape too can be seen signs of equally important changes that have taken place in the local economy, in the practice and organisation of agriculture. Again, it is in the east and north that these are most apparent. Here can be seen the scars of spade-rigs in fields that have not been tilled within living memory. The prolific growth of bracken and furze in the fields near the shore shows the reversion of arable to rough grazing. These are signs of less intensive utilisation of the land now than in the past. Another landscape expression of change is the broken fences, the field banks that have been removed, the overgrown laneways, all suggesting changes in the size of holdings: the disappearance of the carefully tended small farms and their absorption in the larger units of today.

The landscape provides one index of rural change, but it is from statistical sources that the extent of the changes can be most objectively determined. Changes in the settlement pattern show that depopulation is ultimately the major cause of change, and in fact the total population has declined by 31 per cent between 1890 and 1955; but the decline has been twice as great in the clachans as in the dispersed farms.

By examining changes in farm sizes the social group which lost population most severely can be clearly seen (Table I, p. 296).

The period saw not only a decline in the total number of holdings (32–20); it also saw the disappearance of the 5–15-acre farm as the dominant group, and a corresponding rise of the 30–50-acre farm as the modern norm.

The rise in the number of farms over 50 acres is equally significant; in 1890 they formed only 9·3 per cent of the total number of holdings; in 1955 they formed 15 per cent, and one farm in fact exceeds 100 acres. The significance of this change

TABLE I

Number of farms in each size group expressed as a percentage of the total

SHEEPLANDS

	Acres 1–5	Acres 5–15	Acres 15–30	Acres 30–50	Acres 50–100	Acres over 100	Total of holdings
1890	6·2	40·6	25·0	18·7	9·3	–	32
1955	–	25·0	20·0	40·0	10·0	5·0	20

TABLE II

Occupations of heads of households

SHEEPLANDS

	Farmers holding *more* than 16 acres	Farmers holding *less* than 16 acres	Agricultural labourers	Others
1890	13	15	6	4
1955	15	1	12	1

can be further seen in the occupational structure of population in the townland (Table II).

Here it can be seen that the number of larger farmers has remained relatively stable, but the smallholders have almost disappeared. The number of agricultural labourers has increased, but this is not a simple case of the smallholders becoming the landless labourers of today; eight of these men are 'strangers' to the townland.

These are the social changes which are reflected in the pattern of settlement and land holdings. The compact holdings of the Protestant farmers have all remained constant in size and ownership throughout the period (Fig. 3); and although population has declined in this area too, this is entirely due to a decrease in the size of families. On the other hand, the small farms of the clachan dwellers have almost disappeared. In 1890 there were nineteen farms, averaging 15 acres, owned by people living in the clachans. Today there are seven, and three of these are held by people now living outside the townland. Between 1890–1955 there has therefore been a considerable decrease of population (60 per cent), and a wholesale change in the size of holdings, only five of which have remained unchanged in size during the period.

Before analysing the factors that have caused this dramatic change it is necessary to place them in their wider setting, for these are not isolated changes, peculiar to one townland. Professor Evans (1), (2) and Dr. McCourt (3) have shown that changes in the pattern of settlement—the disappearance of nucleated clusters and the appearance of dispersed farmsteads as the modern norm—are characteristic of

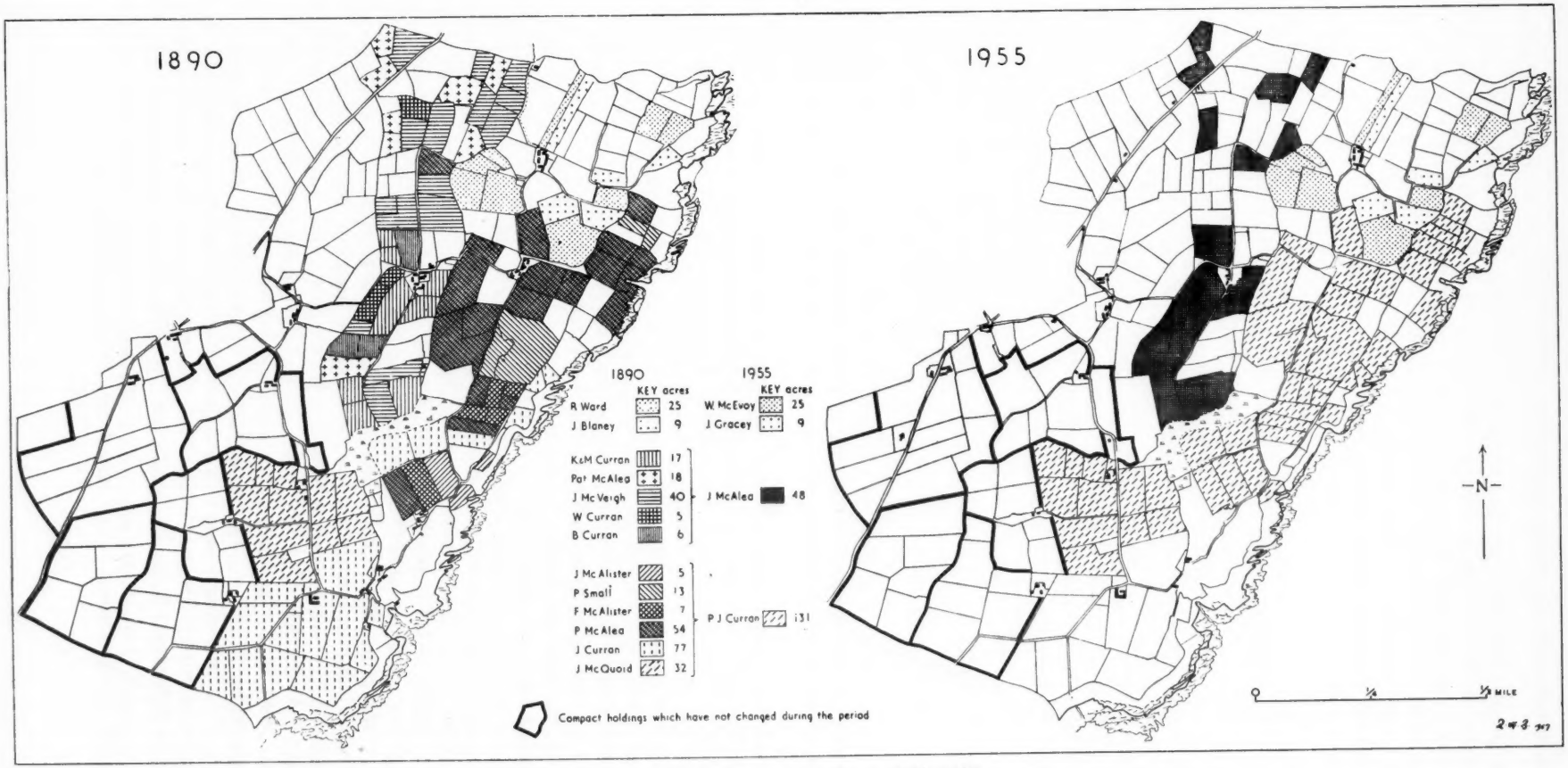

Fig. 3.—*Changes in farm-holdings*, 1890–1955.

rural Ireland over the past two centuries. They have shown that this change is associated with a change in agricultural organisation, from the open-field rundale system to the individual holdings of today. Rural depopulation has also become an accepted fact of Irish social history, especially in the half-century following the great famine of 1845–7. Concomitant with this has been a change in the size of agricultural holdings, as shown in Table III below.

TABLE III [1]

Number of farms in each size group expressed as a percentage of the total

NORTHERN IRELAND

	Acres 1–5	Acres 5–15	Acres 15–30	Acres 30–50	Acres 50–100	Acres over 100	Total of holdings
1890	12·2	34·2	28·7	14·2	8·0	2·6	118, 212
1953	13·4	22·9	23·5	18·0	16·0	6·2	80, 929

In the six counties of Northern Ireland (as in Sheeplands) the 5–15-acre group of farms is no longer the dominant group, while the most striking increase has been in farms over 50 acres. These now form 22 per cent of the total, against 10 per cent in 1890.

Clearly the trend towards larger holdings is the same on both the local and national scale. In Northern Ireland as a whole the trend is usually explained in terms of larger holdings being more economic to farm under modern conditions. As Dr. J.M. Mogey has written: 'Small farms of less than 10 acres cannot support a man and his family today except under conditions of specialised agriculture' (4). Is it this economic factor which has caused these profound changes in Sheeplands? Have the smallholders been forced to sell the land, which under present conditions could no longer give them even a bare subsistence?

Altogether fourteen holdings in the townland have lost their separate identity during the past half-century and have become merged into larger farms, yet in only two cases has the economic factor been the major consideration, both of these being 6-acre farms. Among the remaining twelve farms seven disappeared because the holders were either unmarried or had no children, two had to be sold because of the general debility of the owners, leaving three farms which passed down through normal inheritance from father to son but which now form the nucleus of larger holdings. In Sheeplands, therefore, the primary reason for the disappearance of the smallholdings was the sheer inability of the people to reproduce themselves, to bear children who could inherit the family farm and thereby maintain the separate individuality of the holdings. In fact, of the nineteen farmers who held land in 1890, in twelve cases there were no children to inherit the land, either through celibacy—the most common factor—or through childless marriages.

Lack of desire to marry is in fact one of the most striking features of social life in the clachans during the last decade of the nineteenth century. Of the thirty-four people of marriageable age in the clachans in 1890, twenty-three were single, and

[1] Figures based on (1890): *The Agricultural Output of Northern Ireland*, 1925 (Belfast, H.M.S.O., 1928), p. 82; (1953): *Ulster Year-book*, 1956 (Belfast, H.M.S.O., 1956), p. 65.

of the eleven married couples, only five had children. The reasons for this celibacy and high incidence of infertility seem to be threefold. Firstly, the rate of emigration was high, and most families had brothers and sisters overseas, especially in the U.S.A. Those who left home were usually the younger children, sons who were not to inherit the land, for subdivision of holdings was not commonly practised. This meant that the children who were left behind with their parents to work the land had to postpone marriage until they inherited the farm; and postponement often meant no marriage. Secondly, it was often the more virile element of the population that emigrated. Among those left, poor health was common, due to a low level of subsistence which often reached extreme poverty, to poor housing, and to extreme inbreeding of families. Tuberculosis was a particular scourge; one man remembers thirty young people dying of it while still in their teens. Thirdly, since most families were closely related, this meant that choice of marriage partners within the townland was strictly limited, e.g. one household had first-degree relationship with forty-four individuals in the townland out of a total population of one hundred and forty-nine. This may seem an unimportant factor, but in fact the spouses of the parents of this 1890 generation all came from within little more than a two-mile radius of their homes. As well, the Church discouraged marriage between cousins, and where marriage between close relations took place a high degree of infertility resulted.

The principal causes of depopulation and the emergence of large holdings in the clachan area today were therefore a low marriage rate and a high incidence of childless marriages. That social rather than economic factors were the primary causes of change can be further seen from the manner in which the holdings disappeared.

Where possible the land must remain in the possession of the family. That was the accepted rule, for the people of Sheeplands display the traditional values of all peasant societies in their passionate attachment to the family land. If there were no children in the family to inherit the land, the farm would pass to the nearest blood relation; only in the very last resort would the owners endure the social disgrace of seeing the land sold to a stranger. Thus of the fourteen clachan holdings which disappeared between 1890 and 1955, six were absorbed in larger holdings through direct or indirect inheritance; for example, one farm was inherited by a grand-nephew by marriage of the original owner. Of the remaining eight holdings three had to be sold on the death of the owner, there being no relations to inherit, while the other five farms were acquired by their present owner through mortgage.

Mortgage seems to have been an important factor in the disposal of small holdings after the passing of the 1903 Land Act established peasant ownership of land. Mortgage meant that for the first time land could easily be converted into ready cash. That this meant alienation of the land, does not seem to have been readily appreciated by many of those who consented to it. To an ageing population, particularly to people who had never possessed more than a few shillings of ready capital, and who had as yet no old age pension to provide for them, it seemed to offer untold wealth and a certain security for the future. Yet mortgage was always the last resort, and where it was adopted it frequently left an aftermath of bitterness. Indeed one ambitious local family, who exploited the mortgage to the full as a means of increasing the size of their holding, are still derided as the 'land-grabbers'.

In this paper some of the changes that have taken place in the landscape of an Irish townland during the past sixty years have been examined. By relating the pattern of settlement and land-holding to the social structure of the community it has been shown that depopulation and the disappearance of the small farmers as a social group were the ultimate causes of landscape change. These changes, which are typical of many parts of rural Ireland, have hitherto been explained in terms of

changes in agricultural economy and general standards of living; yet these have not been the only causes in Sheeplands. Here equally significant social changes have profoundly altered the social structure of the townland within two succeeding generations. This is not to imply that social changes such as these have been of equal importance elsewhere in the country. At the same time this study does emphasise two main points. Firstly, it stresses the danger of generalisation based solely on statistical data. This often tends to emphasise one specific factor and ignore others which may be of equal importance but which are not easily discernible in official statistics—or indeed which may not be amenable to statistical analysis. Secondly, it emphasises that detailed studies of small sample regions are essential for the development of more general theories. Not only do they often provide a salutary antidote to over-generalisation; they also reaffirm the importance of the holistic approach, viewing habitat, economy and society as a single functioning entity. Only by using this approach can the relative importance of the varied factors which produce rural change be adequately assessed.

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(3) McCourt, D. (1950): *The Rundale System in Ireland* (Ph.D. Thesis, Queen's University, Belfast).
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SCIENCE AND THE CULTURAL BACKGROUND OF EDUCATION

SECTION L (Education) devoted the morning of September 11, 1957, at Dublin to a discussion of 'Science and the cultural background of education'. Mr. R. R. Hancock, Headmaster of the Northern Grammar School for Boys, Portsmouth, discussed the contribution of the Sixth Form to contemporary society. Professor J. J. McHenry of the Dept. of Experimental Physics, University College, Cork, then presented a paper entitled 'Science in education', which argued that, without any sacrifice of educational ideals, science courses could partly replace the humanities in school and university and be more useful in a changing world. Mr. Hancock's paper is printed below.

THE CONTRIBUTION OF THE SIXTH FORM TO CONTEMPORARY SOCIETY

By Mr. R. R. Hancock

The University of Cambridge annually awards a prize, the qualification for which, as laid down by the pious donor, is an essay on some attribute of the Deity, until such time as the Master of Clare shall decide that the subject is exhausted.

Although the Master of Clare does not appear to regard his field as completely covered, I imagine there may well be many people firmly convinced that this question of the Sixth Form curriculum has indeed been exhausted, so much has it been discussed and pronounced upon in recent times. However, the very fact that so many people, often of eminence and distinction, find something new to say, appears to indicate that, after all, the last word may not have been spoken; and I therefore have no sound excuse for not proceeding.

It would, of course, be easy to produce some magniloquent formula and, relying on that, to make the appropriate deductions. Such a formula could be:

> As education is a function of Society, it is the duty of places of education to provide Society with what it wants.

But it needs little reflection to see the fallibility of this method. For one thing, such a principle could be deemed to justify the monstrous perversions of education that we have seen and still see in totalitarian régimes, where political indoctrination becomes the main function of education.

On a somewhat lower level we have the very real practical difficulty that Society has only the haziest of ideas as to what it really does want; and if that seems to anyone an unjustly hard saying I suggest he should test it by endeavouring to persuade any industrial concern to give precise details of its needs, in type, number and qualifications, of technologists, over the next five, ten and fifteen years!

If we are to have a formula, or even a slogan, for this discussion I would prefer it to be rather that it is the duty of education—and in this, greatly daring, I am including schools—to provide Society with what it needs; and bearing in mind that the real problems of the present and the future are moral and human and not technical, I submit that this means that education must produce men and women properly equipped to make the vital decisions they will find facing them. For it is the great privilege of the generation just emerging that they will indeed have the necessity, not only of serving, but of deciding: and the issues are moral ones.

Education therefore must see that they are vivid, positive and aware; and that they are trained to appreciate the nature of their problems and of their own

responsibilities. They must not be the pallid and ineffectual phantoms of T. S. Eliot's imagining:

> Strained, time-ridden faces,
> Distracted from distraction by distraction,
> Filled with fancies and empty of meaning;
> Tumid apathy with no concentration;
> Men and bits of paper whirled by the cold wind
> That blows before and after time.

I hope this makes it clear that I am thinking in terms of the whole school output, not of any specialist group: of the whole Sixth, in fact, and not just of the science sixth; because I want to make it perfectly clear that I give no countenance at all to the pernicious nonsence of the frequently parroted gibe about 'illiterate scientists'. When we complain that scientists cannot communicate their ideas, we usually mean we cannot understand them, which is not quite the same thing. Scientists, of course, have their own specialised language for dealing with one another just as other specialists do, theologians and philosophers for example; and these have the added complications that they use words in common use with an esoteric meaning, which is even more unfair to the rest of us. But we have the comforting feeling when we hear these specialists that they are using a vocabulary that is familiar; while the scientist's specialised language is quite incomprehensible to us.

But, in point of fact, the good scientist has no difficulty whatever in explaining to the non-scientist what he is doing. It may well be that the bad scientist cannot do this; but we must remember, neither can the bad arts man. The poor exponent of his skill may indeed be illiterate in both cases; the chief difference is that the arts man is illiterate polysyllabically.

However, it would be wholly unrealistic not to recognise that the urgency of the problem we are considering stems from the marked change in the pattern of the employment needs of the contemporary community and especially from the greatly accelerated rate of that change. We have for instance been told officially that we must produce in Britain in the next ten years, 85,000 additional technologists, to use the current neologism which has acquired an almost mystical status as a word of power or incantation. We must necessarily accept this figure and the obligation it conveys, though the precise method of its calculation has not been revealed; but some of the deductions drawn from it appears to be much more vulnerable.

One of these is the vocal, even clamant, demand for what is in effect vocational training in the sixth form; the demand that the schools shall provide, not people trained in a scientific discipline and able and prepared to become efficient technologists, but practising technologists already. This pressure, founded on ignorance of both the purpose and the limitations of sixth-form education, and actuated by fatally short-sighted motives, must, I submit, be resisted.

Not only are schools by their nature and circumstance inevitably the most expensive and least effective method of vocational training, divorced as they must be from vocational practice; but also the enormous range of occupations fed from the grammar school makes any genuine active vocational training for all these jobs quite out of the question.

There is too a further potent factor, actually present in the very position that poses this whole problem, the rate of change in the contemporary industrial scene. If as we are assured, the frequently quoted prophecy of the President of the DuPont Corporation of the U.S.A., applies equally to this country, the fallacy of vocational training in the Sixth becomes crystal clear. You will remember that he said that 50 per cent of the employed population of the U.S.A. is engaged in making and distributing commodities which did not exist fifty years ago; and that the same situation would be reproduced in the next twenty-five years. This means that the

great bulk of children now entering our sixth forms will, at the height of their power be engaged in producing and distributing things which do not today exist. To attempt vocational training for such conditions would be a form of crystal gazing even more wildly fortuitous than any present-day educational practices.

I imagine I am safe in assuming you all realise that my attitude to vocational training in schools is the same as that of Calvin Coolidge's preacher to sin—I'm against it; and I hope I have made some of my reasons clear. There is, however, an incidental but vitally significant aspect of sixth-form work which is frequently overlooked, but which should be taken very carefully into consideration on this important topic. I refer to the unique contribution sixth forms can and indeed must make to what I suppose may be called social integration.

So recently as fifty years ago, the professions and the older universities recruited virtually entirely from a limited number of schools and families, where the tradition of both was firmly established and entry to one or both was the normal thing. This situation, while natural enough, was the continuation and result of what Disraeli a hundred years ago saw as 'two nations'; and not the least momentous consequence of the development of the maintained Grammar School in the present century, inheriting the fine tradition of the Public Schools, and particularly their sixth forms, has been the wiping out, for this purpose at least of the distinction between the 'two nations' and the establishment of the reality of the 'career open to talent'. This has been indeed a social revolution of major significance with the most far-reaching consequences and implications: but it necessarily involves the schools in responsibilities and obligations that are equally new. So rapid has been this laudable and desirable development in recent years that we now find the majority of candidates for the professions and universities, that is the majority of sixth formers are not only first-generation sixth formers, but in very many cases first-generation grammar school pupils. That is, they increasingly are the offspring of parents who have themselves not had grammar school experience, and, however well-disposed and self-sacrificing, as the vast majority are, are unable to give their children the 'background' of academic experience, and sometimes to recognise the insistent and comprehensive demands in time and outlook required by the sixth-form course. There is frequently a great lack of books and of the wide experience needed for the development of the qualities the universities will seek. It used to be said that Oxford awarded history scholarships on father's conversation; and while as a Cambridge man I should hesitate to dogmatise about that, it is clear that, if the qualities sought by college tutors are fostered by the experienced and cultured home, pupils from homes without these advantages will be handicapped, both as entry candidates and as people, unless the schools can fill the gap.

This problem, though little publicised, is a really urgent one. If we do not solve it, we shall certainly produce a kind of culturally and socially de-tribalised intelligentsia: and a succession of frustrated generations of Angry Young Men—what a head master recently described as Jimmy Porters educated by Lucky Jims—could be even more lethal to our way of life and to our standard of living than a shortfall in the output of technologists. In fact, since there is no real dichotomy between these two situations, we should be fully justified in saying that a shortage of technologists would constitute a far less grave danger to our future than a large supply of inadequately educated ones.

This virtually brings us back to where we started. We have at least stated the problem, with I imagine some comforting degree of agreement. Now there is the much more difficult task of suggesting a solution: and I am not sanguine enough to anticipate unanimous support for the proposals I shall put forward. If however my suggestions stimulate wiser men to consider the problems again and to arrive at better conclusions, my time will not have been wasted, nor—which is much more important—will yours.

In order to try to provide what I hold should be the kind of product the schools should be turning out from the sixth forms, I submit there should be a combination of specialisation and properly organised general studies; and that the sixth-form course shall include appropriate experience under four main headings:

1. Religious, moral and philosophical.
2. The humanities—the arts, literature, music, history and geography.
3. Mathematics and science.
4. Communication: skill in the use of the native language, both written and spoken; and effective practical use of one at least foreign language.

To deal with this in somewhat more detail, and first of all, specialisation. Staunchly opposed as I am to vocational training, I recognise none the less that the urgent need is for specialists, and I gladly accept the necessity of specialisation in the sixth form, both as answering the needs of the community and on educational grounds. It must, of course, be the right kind of specialisation, and at the right time: and this time is in the sixth form. The function of the Main School is to give a full general education and the only stipulations I need to make at this stage about the main school curriculum are that it must include an introduction to all the major disciplines; and that it must make entry to both 'sides' of the Sixth, science and arts, open to all children. Clearly there may be an element of selection in the main school to suit the bent or stimulate the interest of each child: but there must not be the degree of premature specialisation which would condition beforehand the choice of 'side' in the Sixth, or which would preclude any broad specialisation at that stage because the necessary preliminaries had not been studied.

In the Sixth specialisation should have two characteristics. It should be in a particular field of study, and it should be limited to the extent of commitment which permits the maximum intellectual development of the student. I am thus opposing the basic concept of, for example, the French Baccalaureat, or indeed the old-fashioned 'Matric', with its spread of six or seven subjects all taken to the same level. This tends to superficiality of treatment, to overloading the curriculum, to concentration on the acquisition of factual information rather than to the stimulation of intellectual curiosity and the habit of inquiry, and tends too often to fail to 'stretch' the intellectual capacity to the maximum in the direction in which it is most capable of advance. The corresponding reverse danger of unduly narrow specialisation—of knowing more and more about less and less—is avoided by the requirement of advance in a 'field of study' and not in a single subject: and by the necessity of experience under the four headings I have already given.

This brings us to the question of general studies, experience in disciplines outside the field of specialisation. This is clearly a knotty and difficult question and one which has triggered off a great number of discussions and statements of views—or even of prejudices, but there are encouraging factors. The necessity of something in the nature of general studies is widely accepted, and even in the most specialised technical institutes, the 'Monotechnics' of the U.S.S.R., each catering for one single industry, there is a broad foundation course covering the first two or three years and including twelve or thirteen subjects; some of which, for example a foreign language, feature in one form or another throughout the course. I hope it is not necessary, though it is certainly just, to add that the job has been extremely well done in many sixth forms, especially perhaps in the Public Schools, for very many years.

Quite clearly the range, balance and bias of general studies will vary with the particular school, its traditions, staff and equipment. This is not only unexceptionable but positively desirable, so long as the four headings I have given are adequately and honestly observed, and so long as general studies are organised to achieve

two objects. They must offer thoroughly integrated courses which in the words of Professor Vick of University College, North Staffordshire, 'promote independent thought, remove intellectual blinkers and discourage the examination of the bigger problems from one aspect only'; and they must be designed to stretch the intellectual capacity of the student by making the same quality demands upon him as his specialist studies do.

It is for instance worse than useless to serve up a series of unrelated gobbets of information vaguely associated with academic activities outside the field of specialist studies in the hope that somehow they will constitute an education. The History of Science for example is normally as useless a means of teaching arts men what science is about, as the History of Literature is to stimulate scientists to the mastery of a means of communication.

Sir Cyril Hinshelwood's stimulating comment—'Science is not the dryly syllogistic handling of obvious facts. It is an imaginative adventure of mind, seeking truth in a world of mystery'—should be, *mutatis mutandis*, the motto of all general studies. So conducted they can be a real and vital element both of education and of the production of the men and women fitted to hold the responsibilities that will fall to them, and Professor Vick's article on 'Science for the non-Scientist' in the May number of the *Universities Quarterly* gives an admirable example of the way general studies should be approached and conducted.

I do not propose here to go into a discussion of the practical administrative implications of these suggestions; I will only say that in a medium-sized school they should not involve insuperable staffing difficulties; that, to give time for adequate general studies, not more than 60 per cent of the sixth-form time-table should be occupied with specialist subjects and finally that it seems urgently desirable to have available an examination of the kind Professor Oliver of Manchester has been experimenting with, and of recognised status, but it is essential that examination of general studies shall remain wholly and entirely voluntary, and that no pressure to make it compulsory be brought from any outside sources.

This leaves me with only one topic still to put to you, and I have left it until now largely because I am aware that I am even less equipped to discuss this than the previous topics I have raised. I refer to the content of syllabuses, what in fact we are to try to teach. This I believe to be mainly a problem for the sciences. By and large, the best teachers have discovered how to use the humanities as instruments of education; but the comparatively late arrival of the sciences to the front rank in educational responsibilities and the concurrent development of science as the dominant element in the organisation and make-up of material life, have combined to give science the status in the popular mind almost of a 'mystique', which I feel sure most real scientists deplore. In the words of Professor Dingle, 'It is one of the paradoxes of modern life that while—on the material and intellectual side at any rate—it is dominated by science, very few people have any clear idea what science is'.

And what it cannot understand, the public in this case comes to venerate and rather pathetically to credit with powers and verities which those best qualified to judge, do not accept. What G. B. Shaw wrote, in characteristic vein less than forty years ago remains dangerously true today—

> Let the Churches ask themselves why there is no revolt against the dogmas of mathematics though there is one against the dogmas of religion. It is not that mathematical dogmas are more comprehensible. The law of inverse squares is as uncomprehensible to the common man as the Athanasian Creed. It is not that science is free from witchcraft, legends, miracles, biographic boostings of quacks as heroes and saints, and of barren scoundrels as explorers and discoverers. On the contrary, the iconography and hagiology of science are as copious as they are mostly squalid.

Even allowing for characteristically Shavian exaggeration, there is a substantial stratum of fact here, and I have an uneasy feeling that the schools have a considerable responsibility for this state of affairs through faulty science teaching. As a non-scientist and therefore particularly prone to error in this matter, I would suggest that schools have in science aimed far too much at teaching pupils the content of other men's minds rather than training them to discover the capacity of their own.

I am in no position to judge whether or not the universities are still in the position which prevented this country from exploiting Perkin's discovery of aniline dyes and left the foundation of the first scientific chemical industry to Germany, where there were enough trained researchers in the appropriate science; but I am sure we must look at the science syllabuses in our sixth forms and rewrite them with the aim of producing more trained and inquiring, minds, and fewer repositories of out-dated facts of dubious relevance to the contemporary scheme and of suspect scientific validity. But these are dangerous areas for the non-scientist. After all, the business should be simple to scientists who continue, I am given to understand, to base their whole study on two such apparently irreconcilable but quite essential theories as Relativity and the Quantum Theory. With such a scandalously provocative suggestion, I shall be wise to bring this to an end.

To do so, I ask your indulgence for a brief recapitulation of the main points I have tried to make. They are:

(i) The responsibility of education to supply the needs of Society.
(ii) The urgency of the problem created by the accelerated rate of change in the social and industrial patterns and the consequent emphasis on technological training.
(iii) The insistent obligation on the schools to train pupils to recognise and exercise their moral and personal responsibilities in the decisions they will be called on to make.
(iv) The impossibility and undesirability of aiming at vocational training in the sixth forms.
(v) The vital necessity of cultural and social integration for the many recruits to technology from strata of the population without the experience of standards required.

Then for practical measures:

(vi) Specialisation in the sixth form—but not earlier—in one field of study and pushed to the extent of the pupil's capacity. Such study to be limited to 60 per cent of the time.
(vii) A coherent and integrated system of general studies covering experience in the four groups of intellectual discipline as indicated.
(viii) A reconsideration and where desirable a rewriting of sixth-form syllabuses to make them less a record of ascertained fact and more an adventure of the mind and imagination.

And of all these suggestions the most important, and perhaps the only one that really matters, is the inescapable obligation to found and buttress the moral responsibility of each individual and to awake his awareness of his own capacities and duties.

FORESTRY IN IRELAND[1]

by

MR. T. McEVOY

IN CHOOSING to survey in broad outline the origins, history and present stage of development of Irish Forestry, I was influenced by two considerations: (1) many listeners will be seeing Irish woodland for the first time in the course of the Association's excursions and may find this background information of value; and (2) there is very little published information of this nature available outside the pages of Departmental reports and specialist journals.

The native flora of Ireland differs in some respects from that of Britain, these differences being associated with the particularly mild Atlantic climate and the breaking of the land bridges which connected Ireland with Britain and the Continent before the European flora had reached the climatic limits in its recolonisation after the glacial epoch. To the forester and the botanist the natural occurrence and survival in Ireland of a Mediterranean species such as *Arbutus unedo* poses a question. Did it arrive in some later inter-glacial period by direct overland route from Spain and survive the last glaciations? If so, why are species of more northerly distribution such as lime, hornbeam and beech missing from the native flora? It is presumed that these species were slower migrants through Britain and were faced with the barrier of the Irish Sea which was formed some time before the English Channel. The disappearance of Scots pine from the native flora after its comparative abundance in the Sub-Boreal period is another mystery. Climatic deterioration played its part, but human agencies must have accelerated the process. While it ceased to be a species of any importance it may have survived, as tradition suggests, in a few refuges until comparatively recent times—and recent pollen analyses lend colour to this possibility. Whatever the answers to these questions, the general composition of the natural woodland of Sub-Atlantic and recent times is clear. Oak was the dominant climax species, sessile in the siliceous hill country, but probably pedunculate on the deep limestone drift soils of the Central Plain. Ash, with wych elm in subordinate role, appears to have been an important constituent on the lime-rich soils, and probably the dominant on shallow soils over limestone pavement in the West. Alder was abundant in the marsh and fen of the Central Plain and in the west especially with ash on the heavy shale soils of the Carboniferous Coal Measure series. Birch was abundant on the siliceous soils of the hills especially at higher elevations. Mention has already been made of *Arbutus*, which was once probably frequent over a large part of the western woodland from Kerry to Sligo, while two other evergreens, yew and holly, were abundant, contributing to the evergreen shrub layer which give an almost Mediterranean appearance to the Killarney oakwoods.

The clearance of the primaeval forest was a long process of attrition. During the historic period Ireland has been troubled by frequent, if not incessant, warfare; and the documents that have survived from early times are meagre and relate for the most part to matters military, political and religious—dynasties, battles, foundations of abbeys, etc. The economic history of Ireland remains very much a closed book and it is possible from casual references only to surmise the forest history. The clearance process must have been continuous from the Iron Age onwards and there is a suggestion of a peak of agricultural activity around the eighth century. By the Norman Invasion (*c.* A.D. 1200) clearances were extensive and the Norman

[1] Address by the Chairman of the Forestry Sub-Section, delivered at the Dublin Meeting of the British Association on September 5, 1957.

influx merely hastened an economically desirable agricultural reclamation. By comparison with England and the Continent Irish agriculture was characterised by its emphasis on livestock, especially cattle on open range, in a climate which allowed all-the-year-round grazing. Under this system regeneration would be lacking and the forest would be gradually thinned out even without recourse to extensive fellings. Incidentally, the Normans added the rabbit and the fallow deer to the herbivorous enemies of the forest.

From the thirteenth to the sixteenth century there are occasional references to the export of Irish oak to Wales, London and even Holland. Apart from its local use for building and firing, however, timber did not become recognised as a valuable article of general commerce and industry until the sixteenth and, more especially, the seventeenth centuries. By then all the indications are that timber was becoming a scarce commodity. Military considerations also entered the picture and the Elizabethan state papers have frequent references to the problems of conducting warfare in the 'woods, bogs and fastnesses' which had become the refuges and bases of the native militia. From the records one gets the impression of a country in which the plains were comparatively free of dense forest but with fairly well defined concentrations of woodland, mostly in the mountain valleys and glens of Wicklow, of Munster and in the O'Neill country around Lough Neagh in Ulster. The references to Connaught are vague and confusing and leave one with the impression that the chroniclers lacked first-hand information. The seventeenth century was marked by extensive plantations, not of trees, but of settlers and 'adventurers' from Britain. Those new landowners held their land at the pleasure of Crown or Parliament and by force of arms against the dispossessed Irish. Their tenure was uncertain and it is hardly surprising that they lost no time in converting their timber capital into a more liquid form. There was a growing scarcity of oak in Britain and much of the accessible large oak was promptly felled and exported as ship and building timber or for cooperage. At the same time iron furnaces and bloomeries, using both native and imported ores, sprang up in the remaining woods and continued in operation until they were completely exhausted. The Earl of Stafford is reputed to have made one million pounds from smelting in Co. Wicklow. This activity reached its peak around 1641, when it was somewhat interrupted by renewed conflicts. By the turn of the century most of the woods had gone but smelting with local charcoal continued in a few places until 1770.

The seventeenth century was the great age of commercial exploitation of Irish timber and the end of the Williamite Wars (1691) marked the exhaustion of this natural resource. For fully twenty years afterwards the state of Ireland did not permit the general practice of the peaceful art of tree planting. It is a remarkable fact that no plantations of any consequence existed in Ireland before 1700 and that even such a common tree as beech was not introduced until around that date. The eighteenth century saw the change over from fortified house to country mansion and the laying out of demesnes, which according to the fashion were planted with groves, belts and avenues as well as park trees with a view to improving scenic, amenity and sporting values. Around 1700 the trees introduced included Scots pine, various elms, Spanish chestnut, lime, walnut, hornbeam, sycamore, evergreen, oak, plane, robinia, mulberry, Lebanon cedar, and Norway spruce. European larch came in as a specimen tree about 1738 and common silver fir probably about the same time.

The results of almost a century of such planting are indicated by the estimate of the area under 'woods and plantations' for 1791 which was made fifty years later, in 1841, when the regular collection of agricultural statistics was begun. Before quoting such figures it is well to realise that such statistics collected by the police without the possibility of an independent check may not be very accurate, and that the interpretation of the heading 'woods and plantations' may vary over

a long period, so that strict comparisons are not possible. The figures do, however, indicate definite long-term trends in the woodland acreage. For 1791 the estimate was 105,000 acres of which 20 per cent was oak, 70 per cent mixed and the remaining 10 per cent ash, elm, beech and fir (= Scots pine). An interesting point is that little more than a century and a half back the area under conifers was estimated at a mere 1,612 acres. It is possible that the figures referred only or largely to the protected demesne woods and took no account of neglected remnants of natural woodland and scrub elsewhere. According to Arthur Young in his *Tours in Ireland* (1776–9), however, the country outside the demesnes presented a bare and desolate aspect for want of trees and we are forced to the conclusion that, in spite of almost a century of planting, woodland amounted to only one-half of one per cent of the land area. In these circumstances and with a rapidly increasing population, it is not surprising to find that timber prices were high and that, as the early plantings matured, landlords were attracted by the financial rewards. Planting mounted from an average of 2,500 acres per annum in the decade 1791 to 1800 to 6,500 in the decade 1831–40. The woodland area was thus trebled in half a century to close on 350,000 acres. During the Napoleonic Wars prices for oak timber and tan bark were exceptionally high and optimistic forecasts of the profits from hardwoods undoubtedly contributed to this achievement. It is fair to say that forestry in the commercial sense dates from the early years of the nineteenth century. Previously, the only systematic forestry practice was the coppicing of natural oakwood, in almost all cases without leaving standards on a 30–40-year rotation for the production of small timber, tan bark and charcoal.

After the Napoleonic Wars the market for oak coppice failed and it was allowed to develop into high forest, in most cases the number of stems per stump being gradually reduced to one. Much of this type of woodland survived until the two World Wars created a temporary market for small oak timber and firewood and reduced the acreage of recognisably native origin to an area probably less than 10,000 acres.

The changing pattern of the timber market induced by the Industrial Revolution, and the satisfactory growth of the European conifers under Irish conditions led to an increasing reliance on them in afforestation from about 1820 onwards. Larch and Scots pine now took the lead in new planting. By 1891 there were over 107,000 acres of conifers, as against 60,000 acres of hardwoods and some 140,000 acres described as 'mixed'.

In so far as the composition and productivity of woodland was concerned, this date may be taken as the high-water-mark of private forestry, but the tide was already on the turn. From 1881 onwards a long series of Land Acts provided for the transfer of title in all tenanted land from landlord to tenant and by 1923 the landlord as such ceased to exist. An unfortunate side effect of the process was the break-up of estate woodland, especially the woods outside the demesne walls. The Land Commission, set up to supervise the transfer of ownership, had no funds which could be applied to the purchase and retention of standing timber so that it became equally an embarrassment to landlord and State. The timber merchants flourished on an easy market, aggravated by the great storm of 1903.

In the first five years of this century clearing exceeded planting by 50 per cent leaving, in round figures, 300,000 acres of woodland. By 1921 the area of private woodland, in round figures was 280,000 acres, of which 240,000 acres were in the Twenty-six Counties. But the area statistics tell only part of the story. The woodland still classed as such was subject to repeated culling for the most saleable trees, especially during the war years, and many of the woods became seriously understocked and consisted largely of trees of firewood quality.

It is against this background of private forestry in decay that direct State intervention must be viewed. Under pressure from public opinion the Gladstone

Administration in 1880 initiated a trial afforestation scheme on 820 acres of Connemara rock and bog. Almost every conceivable European species was planted in extreme Atlantic exposure and only Maritime pine made any show in a few sheltered hollows. The scheme was abandoned in 1889. In 1903 a more promising start was made when the Avondale estate of 550 acres in County Wicklow was acquired as a demonstration forest and a 'training school for working foresters'. In 1908 a Departmental Committee on Irish Forestry recognised the impossibility of meeting home timber requirements from private resources. It recommended direct State participation to the extent of planting 200,000 acres of bare land over a 40-year period and the acquisition and management of the larger blocks of woodland coming on the market as a result of the operations of the Land Commission.

By 1922, when the Irish Free State came into being, 3,500 acres of standing woods had been taken over and 3,500 acres of bare land planted—3,200 acres south of the Border. Planting mounted from 1,000 acres per annum to an average of 2,500 for the first decade of native government in the Twenty-six Counties. In the following seven years up to World War II, the figures continued to increase, the average being 6,000 acres. War and its aftermath reduced the average for the next seven years to 4,750 acres. The average for the next five years rose to some 7,000 acres. For the last five years the average has been 13,750, with a maximum of 17,500 in 1956–7.

The State forest lands now amount to one-third of a million acres, of which 286,000 are classed as productive forest land and 237,000 acres are under forest crops. For management purposes the forest estate is divided into 173 forests, which give direct employment to 5,000 men.

To complete the picture, we must take a final glance at private forestry. It is unfortunate that the creation of the State forests was not accompanied by at least a maintenance of area and stocking of private woodlands. But the State acquisitions were made to some extent at their expense: 30,000 acres were stocked woodland and 55,000 acres were cleared woodland or scrub. So 85,000 acres, which may originally have been classed as private woodland, have been absorbed, accounting for a reduction of roughly one-third. A comparison of the figures for private woodland in 1921 and 1956 show a reduction by half from 240,000 to 120,000 acres, indicating clearance, or at least recognition of the loss of, a further 35,000 acres.

A Census of Woodlands in 1942 threw a revealing light on the condition of this private woodland. Of the 108,500 acres in woods of $2\frac{1}{4}$ acres or more, only 1,616 acres were under twenty years old. Average stocking per acre for the 130,000 acres covered by the Census was only slightly over 1,000 Hoppus feet, divided fairly equally between firewood, commercial hardwoods and commercial softwoods. This may be accepted as a representative figure for private woods at that date, and their condition has hardly improved since. Taking into account the good land on which they are situated and the great preponderance of mature woods, the figure indicates an extreme degree of understocking of commercial timber. Increment under such conditions could be only a small fraction of the potential.

Private planting is subsidised by State grants to the extent of £10 per acre. Under this scheme planting has averaged 350 acres per annum over the last nine years, a rate which is obviously inadequate in relation to total acreage and age-classs distribution and stocking.

Nevertheless, there have been welcome signs of a revival of interest in private forestry for profit on good land. Even if private resources never make a major contribution towards home timber requirements, it would be unnatural and unhealthy if forestry were in practice to become a State monopoly. For the first time a number of estates are now organising their woodlands on a working plan basis. Over-mature woods are being felled and replanted and the surplus revenue used in

restocking derelict areas and bare land. It is hoped that the growing volume of produce from the State forests will lead to a more rational and steady market and make possible a more efficient timber utilisation industry—conditions essential for thriving private forestry.

Reverting to the State forests, we are now in a position to examine more closely their development and composition. Perhaps their most peculiar feature results from the way they are built up. By British standards Irish farms are extremely small, typically between 15 and 30 acres, with only some 7,000 holdings over 200 acres in extent. In the mountainous districts where acquisition is active the holdings often consist of several detached plots and to complicate matters still further, often include a share in a grazing commonage. The land must be acquired from the owner who is himself working it, not from a landlord who enjoys no more than a rent interest. Despite these inherent difficulties, some 2,400 acquisitions averaging 140 acres have been effected without resort to compulsion. The typical forest now consists of many detached plantations and is quite unlike the traditional picture of a forest as a large unbroken tract of woodland. The acquisition process has been likened to the completion of a jigsaw puzzle on a gigantic scale.

As an example Tallow Forest, Co. Waterford, is quoted. Over a period of 30 years a forest of 5,000 acres has been pieced together from 63 acquisitions, not one of which was a square mile (640 acres) in extent. The number of separate woodland blocks is now 35, scattered over a district of 100 square miles and occupying 5 per cent of the land surface.

Another result of the fragmentation of holdings, and the concomitant significance of rough grazing as a supplement to the small arable acreage per holding, is the difficulty in acquiring land of good forest quality, especially with the high livestock and wool prices prevailing since the last war.

The age-class distribution is of course quite abnormal. Of the stocked area about 50 per cent is in the 1–10-years class, about 20 per cent in each of the classes 11–20 and 21–30 years. The remaining 10 per cent is in the 'over 30-years' class, comprised about equally of acquired woods and early State plantations. Within the individual species this abnormality is most marked in the case of *contorta* pine. This species accounts for some 20 per cent of total planting, perhaps 45,000 acres in all, of which over 75 per cent is in the 1–10-years age-class and less than 7 per cent is over 20 years old.

Reliance to such an extent on this comparatively unknown species is perhaps the unique feature of Irish forestry, a feature imposed by difficult soil and climatic conditions in the areas available for planting. Before 1950 very little was known of *contorta* pine elsewhere. Its silviculture had been largely ignored in its native habitat on the west coast of North America. New Zealand was understood to have some 3,000 acres of plantations, but there was no evidence of a continuing interest in it. Norway and Denmark had a few small plantations, more in the nature of provenance trials. The British Forestry Commission had used it on a very small scale—largely in the form of experimental plantations. Irish foresters have noted with interest its recent acceptance in British forestry, where some 60 million plants have been used since 1950 and where it accounted for 13 per cent of plants used in 1956. It appears that Ireland still has the greatest area of *contorta* pine plantations, but it looks as if Britain will soon take the lead in this respect.

Thinning in appreciable amount began in 1937 with a 700-acre programme and last year reached 11,000 acres with a yield of 3½ million Hoppus feet. In the early years, thinning grades were related to the slower growth and response of European conifers, and has given stands of the faster growing species with rather restricted crowns and low girth/height ratios. Current practice tends towards much heavier early thinning, with a view to promoting good root-hold and resistance to stem breakage in exposed situations. This is a field in which experience is still very

limited and much remains to be done before thinning schedules, suitable to Irish forest and timber-market conditions, can be prescribed with any degree of assurance.

Considerations of thinning practice lead naturally to the question of gale damage. In 1935–6, just when appreciable areas were entering the thinning stage, much damage was done by strong winds accompanied by snow freezing on the crowns. Douglas fir in the small pole stage proved particularly vulnerable on heavy soils.

The first major blow-out of valuable timber occurred in a freak storm, accentuated by severe icing, in the Slieve Blooms in 1954. In this one locality about 750,000 Hoppus feet, mostly of Sitka spruce around 40 years old and 70–90 feet high, were uprooted or broken. While strong winds were general, serious damage was confined to the district where they were accompanied by severe icing. This was the first large block of advanced Sitka spruce to come on the market. It was cleared at satisfactory prices and reports on timber quality have been extremely favourable.

Ireland escaped the full severity of the Scottish gale of January 1953, but in February 1957 a very similar gale, which veered from south-east to south-west with recorded wind speeds up to 108 miles per hour, struck the whole country. The volume of timber blown in the State forests is estimated at 3,000,000 Hoppus feet, mostly from conifer plantations over 50 feet high, with Sitka spruce predominating. Practically all species were affected and it is difficult to trace any consistent pattern related to species, topography or soil conditions. It seems that gusts of quite exceptional force were capable of throwing almost everything in their path. The blown material contains a higher proportion of clean-grown saw timber than comes on the market in thinning sales and clearance is being effected at satisfactory prices.

We left the discussion of the use of species at the end of the last century when European conifers dominated the scene. The West American species were introduced to Irish arboreta towards the middle of that century but their use in plantation lagged behind Britain. In fact they do not appear to have been so used to any extent before 1900. The minutes of evidence of the 1907 Committee still show a concentration of informed forestry throughout on Scots pine and European larch with Norway spruce a poor third. Professor Augustine Henry was then the only advocate of the West American trees, lending characteristic point to his argument by saying that Norfolk was more akin climatically to Korea than to the west of Ireland. However, by 1922 Forbes was able to report the use of a substantial proportion of these trees in the State plantations, to comment on their behaviour in pure crops and (on the basis of his experience) to recommend mixtures of European larch and Douglas fir and of Japanese larch and Sitka spruce. Since that date they have remained important constituents and, with the increased concentration of planting in the 1950's on western and exposed areas, Sitka spruce and *contorta* pine now account for 70 per cent of all planting.

It is interesting to examine the expansion of planting in relation to the growth of silvicultural knowledge. Up to the 1940's planting was confined to good forest lands becoming available as the result of the break-up of estates in the lowlands of the Central Plain, and to what was considered safe forest land in the hill country of the eastern and southern counties and in the Slieve Bloom mountains. The semicircular spade and mattock were favoured as planting tools. During the 'thirties, planting on upturned turves was generally adopted on wet and peaty ground and *contorta* pine was coming to be recognised as a very hardy pioneer. These two advances encouraged the forester to tackle more westerly and poorer peaty areas in Cork, Kerry and Donegal and in the hills of east Clare and east Galway. The 'forties may be regarded as a period of consolidation rather than

expansion, with special attention being given to the establishment of hardwoods. Anderson groups of 13 or more hardwoods, 12–18 inches apart, were set at 20-foot intervals in a matrix of conifers, usually Norway, Scots or larch. After a slow start many of these groups are now very promising, especially oak and beech.

The 'fifties have seen the end of post-war shortages. High agricultural prices made difficult the acquisition of better types of forest land. At the same time the remarkable success of *contorta* pine on poor and exposed sites was encouraging. A study was made of the outstanding research work of the British Forestry Commission in the establishment of plantations using tractor ploughing and phosphatic manuring and these methods were promptly adopted. The circumstances were thus favourable to an extension of afforestation into the higher rainfall blanket bogland, especially in Galway, Mayo and Donegal, which has become the particular feature of the 'fifties. It would be wrong to over-emphasise this change. It came as the logical conclusion to past successes and improved techniques. Further, the approach to the afforestation of blanket bog remains strictly selective; there are many variants of the type and normal planting is confined to situations where topography, peat type and shelter are above average. Only a limited amount of purely experimental planting is done on the flat, deep peat expanses which comprise the typical and most widely developed *facies* of blanket bog. Apart from the low fertility of this *facies*, drainage in depth presents special problems, water movement in the highly colloidal peat is slow, and the degree of risk from wind is exceptionally high.

Some brief notes on Irish experience with various species may be of interest.

Sitka spruce: This is perhaps the tree, more than any other, which has been in favour at all times in the service and has grown in popularity with the years, until it now accounts for 40 per cent of all planting. It has exceeded all other species in total height growth, one specimen reaching 148 feet in 108 years. In Connemara within 7 miles of the open Atlantic, it has reached 109 feet in a small plantation 49 years old (Quality Class I), with volumes of 70 Hoppus feet per tree. Post-planting check has been eliminated to a large extent under present methods and the tendency is to extend its use, especially as it stands exposure well, is capable of mean annual increments of over 200 Hoppus feet and its timber is gaining a good reputation both for mechanical pulping and sawing. Apart from frost hollows in the Midlands and marginal dry sites, aphis infestation, which became general in the 1930's has not proved serious. *Fomes annosus* (butt-rot) is noticeable in some of the crops over 40 years old and Group Die-back (associated with *Rhizina inflata*) has appeared in several forests. The high proportion of Sitka in recent wind-blows is regarded as an index of the success of this species in reaching the vulnerable height before most others, rather than as an indication of liability to wind-throw.

Contorta pine: The proportion of this species used in planting rose very rapidly to around 40 per cent in 1952 and 1953, but has since dropped to 30 per cent as the use of Sitka extended.

Norway spruce: The use of this spruce has dropped from peaks of 24 per cent in 1942, and 20 per cent in 1949, to around 10 per cent. Its decline is associated with the increased proportion of planting in the west where Sitka has proved markedly more resistant to exposure, often growing well where Norway dies off. Its use is now largely confined to moist fertile soils in sheltered situations, especially in the Midlands where late frosts are severe, and also to old hardwood ground where honey fungus is prevalent. On the best alluvial sites it has given height growth in excess of Quality Class I and has proved a very reliable producer of high quality timber on suitable sites.

Scots pine: This tree had the reputation of a hardy pioneer in the early days of State forestry and was planted with some confidence on poor, leached old red

sandstone soils in the south, but with little success. It has proved disappointing at high elevations except on well drained soils in the east, and *Lophodermium* leaf-cast has been very severe, especially in wet seasons and in stands of Continental provenance. The current view is that it is not really suited to a wet humid climate and it tends to be confined to the drier soils in similar localities to Norway spruce, and often indeed in mixture with it, especially on cut-over raised bog in the Midlands. It fluctuated between 20 and 32 per cent of total planting in the period up to 1951, but has since dropped sharply to less than 5 per cent.

Corsican pine: A small proportion has always been included in programmes and in the twenties it was looked on as a good replacement for Scots pine in exposed areas. In its turn it suffered die-back in some high rainfall areas and it is now regarded as a species for use on the thin soils of the limestone pavement and on gravel eskers, both of which occur at low elevations.

Pinus radiata: Heavy transplanting losses and its coarse branching habit have militated against wider use of *Pinus radiata*, but it has proved hardy and a very rapid grower in most of the country outside the Central Plain. It is particularly resistant to salt-laden winds on the western coast and it has prospered on sand dunes in Wexford. There are a few examples of good growth on western bog and it is likely to be tried more extensively in the future on this type.

Larches: European larch has been used mostly in mixtures with Douglas, Scots, Norway and hardwoods with a view to its removal in thinnings. Poor ripening of leading shoots in wet seasons caused die-back and it has declined from about 8 per cent of planting up to 1940 to 1–2 per cent in recent years. Traditionally, good canker-free larch was grown on pitwood rotations in some of the south-eastern counties (e.g. in the Suir Valley) but little safe larch land is now acquired and the demand for its timber has been erratic and tending to decline. Japanese larch is better suited to well-drained soils in the west, provided exposure is not too severe, and it has been steady at around 4 per cent of planting in recent years. It is usually planted pure in order to break up a plantation against wind-throw and fire as much as for its timber value.

Douglas fir, which was so prominent in plantations up to 1930, suffered a dramatic eclipse, dropping to $2\frac{1}{4}$ per cent of planting by 1935. Initially the reaction was due to the crooked stems and coarse branching of thicket-stage Douglas, especially from 6-foot planting in mixture with 50 per cent larch. By 1937, however, there was heavy defoliation due to *Adelges cooleyi*, possibly accentuated by *Phaeocyptopus gäumanni*, and the crops failed to maintain canopy with consequential severe check in growth. Some of the worst stands were cleared or heavily opened up during the war years. By 1950 there was clear evidence of recovery after first thinnings, especially on lighter soils. The check in thicket stage is now regarded as a passing phase which can be shortened by heavy thinning. Most stands over thirty years old are growing vigorously but Quality Class is depressed by the flattening of the normal age/height curve during the check phase. The trend now is to use Douglas on light soils of moderate fertility in sheltered situations, which in effect confines it to the south-east.

Silver firs: Abies alba is now used only in very small quantities, due to die-back in young plantations following infestation by *Adelges nüsslini* from the 'thirties onwards. *Abies grandis* is preferred in sheltered sites where it can reach mean annual increments of the order of 300 Hoppus feet. Following Northern Ireland's example, *Abies procera* (*nobilis*) is selected as a particularly wind-firm tree for exposed dry sites of moderate fertility.

Tsuga heterophylla has not been widely used but it has proved a heavy volume producer on dry soils on which spruces are slow to overcome competition from grass or scrub. It is also an excellent tree for underplanting and for filling small gaps where there is heavy side-shade. It regenerates freely and home seed collections

are giving good results. Now that its timber has gained a place on the international market it is considered worthy of more extensive use and of trial on blanket bog.

Broadleaf species have already been mentioned but eucalypts deserve separate attention. In the 'thirties a selection of eucalypt species was planted in trial plots but many succumbed to an exceptionally hard winter frost in December 1938, which followed a mild spell. Quite remarkable height and volume growth has been put on by some of the surviving species and further examination of these with special reference to timber quality and uses is now necessary. Amongst species which are promising are *E. mülleri* (or *johnstoni*), *E. urnigera*, *E. globulus*, *E. radiata*, *E. dalyrympleana*, *E. viminalis* (mountain type), *E. gigantea*.

May we attempt briefly to summarise the history of Irish forestry into five periods: (1) up to the seventeenth century—clearance for agriculture and local timber and firewood needs; (2) the seventeenth century—commercial exploitation leading to exhaustion of timber supplies; (3) the eighteenth century—the beginning of planting when hardwoods were laid out in amenity woods; (4) the nineteenth century—the rise and decline of estate commercial forestry using European conifers, and (5) the first half of the twentieth century—the development of State commercial forestry using American and European conifers.

For an industrial concern a half-century is perhaps a respectable age but in the forest it counts but a short rotation during which a single crop is grown and harvested. The forester is very conscious of the short span of his experience with forestry in the modern sense of that term and of the wide field of knowledge still to be explored. He is loth to crystallise his techniques or to set rigid limits to the final extent of afforestation. What he can claim is that the half-century since this Association last met in Dublin has seen a great addition to his knowledge of the cultivation of the European tree species, especially under forest conditions on poor land. He can also claim the creation *de novo* of the art of cultivating with success the new American introductions, leading to their eventual acceptance as the major constituents of the new forests.

This acceptance is of national significance in its implications. It widens substantially the range of available sites on which timber production can be usefully undertaken; and it makes for higher output per acre, a cardinal necessity of the national economy. Almost equally important in an economy short of capital and with an unfavourable balance of payments is the reduction of the time-lag between investment and reward.

In the absence of a specialist research staff, much has been achieved on the basis of judicious assessment of site conditions and careful observation of crop development by field officers. But it would be less than fair to fail to record the debt to British forestry and particularly to the Forestry Commission. Both British and Irish services have been tackling afforestation problems which differ in degree rather than essence. Cordial contacts, both official and private, have been maintained at all times and it is a great pleasure to acknowledge the value of the information received and the infinite patience and unfailing courtesy with which it has been imparted. Now that the Irish service has its own Specialist Research and Assessment Group it is hoped to advance further the frontiers of technical knowledge and to plan research studies on lines which will be of the greatest benefit to both countries.

What of the future? The state planting programme provides for a progressive increase to 25,000 acres from 1960 onwards. Planting on this scale, even on a forty-year rotation, should yield timber very much in excess of current admittedly low consumption. It is not generally realised that thinnings alone from the State forests already exceed by half the volume of all types of commercial timber from both State and private lands in the pre-war period (1934–8). As the volume of thinnings will rise rapidly over the next decade a co-ordinated expansion of

industry based on pulpwood is essential to the forest economy. It is clear that in time pulpwood derivatives will be available well beyond the consumption capacity of the home market. Ireland must therefore produce for export on to a competitive but expanding market. Much of the poor and exposed land, which seems to be an inevitable part of a large afforestation programme, is likely to yield crops of low quality as saw timber but quite satisfactory for pulping or chipping. It follows that it becomes necessary to examine silvicultural practices, originally designed for the growing of high-grade saw-logs, with a view to their adjustment, where possible, to the most economical production of pulpwood.

In a sense Irish State forestry has come of age. Many of the problems of establishing tree crops have been solved. The forester's worry nowadays is not so much *whether* the trees will grow but *how* they will grow and what volume, size and quality of timber they can be made to yield. The advent of this second phase undoubtedly brings many new problems of its own, but to the forester it brings an abiding sense of achievement and satisfaction as he sees his handiwork bearing fruit, beginning to contribute to the nation's purse, and adding to the population on the land and employed in industry dependent on the land.

FISHERIES DEVELOPMENT IN THE COLONIAL TERRITORIES[1]

by

DR. C. F. HICKLING, C.M.G.

I START with one or two assumptions which we may take for granted. One is, that fish is almost everywhere acceptable, and is a most valuable source of protein in a balanced diet. Another assumption is, that the populations of the Colonial territories, thanks to modern medicine, hygiene, and social welfare, will continue to increase at their present rate, which doubles the population every thirty years or so. Even to maintain the present supplies of fish per capita, supplies must be doubled every thirty years.

This in itself would be a tough task enough, but it will be aggravated by certain social trends. Modern means of communication and mass entertainment are beginning to engender a dissatisfaction with the traditional peasant way of life, the common round of hard toil; while the break-up of tribal community life, with its regular festivals, must accentuate what can best be vaguely described as a demand for a rising standard of living.

Among the younger generation, this is beginning to show itself as a movement from the country into the towns. That phenomenon is, of course, well enough known in Britain, and we have our own problem. What these people do when they get into the towns is no concern of this paper. Industrial development, which is likewise making progress, tends to take people away from the country and form them into aggregates which cannot be self-supporting for food.

So far as fish is concerned, peasant communities tend to supply their own, at the subsistence level. How common a sight it is, to see people, men, women and children, fishing on the shore, on the reefs, in rivers, lakes, ponds, and even ditches and irrigation channels, for their own subsistence. Each may take home only a string of little fish, or a couple of handfuls of prawns; but in the aggregate of millions of people, the total must be very great, and none of it may appear in the statistics. People who aggregate into cities and towns, or even large villages, are cut off from what might be called this invisible source of fish, and must depend on the catching and marketing capacity of a class of part time, or more rarely full-time, professional fishermen and fish dealers.

Now, for reasons of past history, the Colonial fishermen are a depressed class, economically not high in the scale. They have been in the grip of a vicious circle of poor resources, and consequent low earnings and lack of capital. They have, in fact, been kept in operation by being tied in debt to local enterprisers who supply the capital equipment, and may keep the fishermen, in return for the right to handle and sell all the fish caught. This is an age-old system; and the fact that it is liable to abuse should not blind us to the essential role it has played. But from the point of view of fishery development, it is not a good system. First, the fisherman has no interest in increasing his catches and no capital with which to do so. His creditor is more often interested in rigging the supply of fish in such a way that he makes a large profit on a small turnover, rather than a smaller profit per unit over a large turnover, which is what the consuming public wants. Secondly, there is the important moral consideration that the fisherman can have no pride in his work, nor incentive to better himself.

[1] Address delivered to Section D (Zoology) on September 11, 1957, at the Dublin Meeting of the British Association.

It must be said, straight away, that the system of the tied fisherman got good results, and it remains to be seen whether the results of fishery development schemes will be as good. In one way or another, the creditor does get work from his debtor fishermen. When the fisherman becomes an independent operator, he is swayed by a new set of motives. This again is a problem well enough known in this country. I know (we all know) cases where an increase in production is hindered, rather than helped, by increased earnings. Able to earn more with less toil, the fisherman may set a proper value on leisure. He may still produce only as much fish as before, but in much less time. Who is to say he is wrong?—yet the community is not served.

That trouble may arise in the future; I can only say, for the present, that fishery development schemes have so far succeeded in their object, namely, to increase the supply of fish by increasing the efficiency of the fisherman and by introducing new resources and new methods. Now I must give some examples, first from the freshwater, and later from the marine, field.

There seems to be less scope for development in the river fisheries than in lake or sea fisheries. Tropical rivers, even more than temperate rivers, show a very large seasonal rise and fall of level. At high water, they frequently overspill their banks and spread far out over the valley in a series of lagoons, pools and marshes. The fish from the river spread out into this greatly increased living space, which is also very rich in food, provided not only by the land plants and insects, but by epiphytic algae and by plankton which quickly develop. So the fish breed, and they and their offspring grow very rapidly; by the time the flood begins to subside, the fish potential has undergone a manifold increase, and this increase is the source of some of the world's richest freshwater fisheries. It has been well pointed out, that heavy floods in temperate rivers are unforeseen, dreaded, and disastrous; in tropical rivers they are regular, welcome, and beneficial.

I can however mention one very useful piece of development in river fisheries. In Ghana (formerly the Gold Coast) the Volta River has been fished for many years by teams of African fishermen who migrate up from the estuary and set up temporary fishing camps. Until recently there were few Africans living by the river, because of the tsetse fly. Now, however, the tsetse has been cleared over long stretches of the river, and the Africans are coming down from the high ground and settling on the river. They are not fishermen; but to enable them to draw on the resources of the river, the Ghana Fisheries Department has organised teams of instructors, and it seems that fishing will soon become an integral part of the way of life of these communities.

This is the more important because, if the Volta Dam is built, to provide electric power especially for the aluminium industry, some hundreds of miles of the Volta will become a vast lake, in which considerable fisheries will develop. The existence of ready-trained communities of fishermen will speed up the exploitation of this future lake.

I might also here say something about the Kariba Lake. You all know that one of the world's greatest hydro-electric schemes is taking shape on the Zambesi. This mighty river becomes compressed, in the Kariba Gorge, into a channel barely 100 yards wide, through which it pours with enormous power. A 400 foot dam is being built across this gorge, and the result will be, in the early 1960's, a lake of over 2,000 square miles. I had the privilege of visiting the scheme last year, to advise on the fishery possibilities of the future lake. As a matter of fact, we have here an almost unique chance to watch a major river change into a major lake, and our research team in Rhodesia has already begun a survey of the river which will be continued until the lake is full, and I hope for many years thereafter, as the lake settles down.

As a part of my survey, I spent a few days on the Zambesi, in the valley which

will be the future lake bed, and thought, at the time, that Tennyson's lines, 'Here rolls the deep, where grew the tree' will be the epitaph of this valley. I borrowed a crocodile hunter's steel canoe, and fished with gill-net both by night and by day, not in the main river, which was in flood and running at five knots, but in a flooded backwater and the estuary of a tributory. The catches were good; in fact I have seldom seen better in fresh water. We averaged about 80 lb. of fish per 60 yard net; an interesting point was the very high proportion of predatory fish, chiefly Tiger fish. It seems to me, that in the comparatively crowded living space of a river, the predators must have the advantage of the non-predators. In the future lake, where there will be very large areas of fairly shallow water, we can expect a better balance between the predators and their prey. For example, in these catches of mine, a total of 44 per cent by weight of the fish were predators, almost wholly Tiger fish. The rest were mostly *Labeo* and *Distichodus*. Yet the future lake may have, as its dominant fish species, some fish too scarce to appear in the river catches, but which may be greatly favoured by lake conditions.

The African tribesmen who live by the river are not fishermen. In fact, they seem to be afraid of fishing in the river.

They willingly accepted the fish I caught; but when I showed them that they were the result of about ten minutes work, easy money, in fact, and asked them why they did not fish themselves, the result was a series of excuses which did not ring true.

An attempt had been made to teach some of them to fish, and I believe the authorities are persisting, and are now having considerable success. It will be a most important piece of fishery development, if by the time the lake comes into being there are trained communities of fishermen using modern and efficient gear. Moreover, it would powerfully help the resettlement of those whose homes and gardens will be drowned by the lake.

To turn to another aspect of fishery development, supplies of fish are being improved by stocking and transplantation. Perhaps the most notable is the transplantation of three new species of *Tilapia* into Lake Victoria. Lake Victoria has two indigenous species, both peculiar to the lake, and both plankton feeders. As a result of the work of the Jinja Research Station, it was considered desirable to introduce a plant-eating species of *Tilapia*, and so *T. zillii* was introduced. Besides being a plant-feeder, and so being able to use a source of food little exploited in the lake, this *Tilapia* is a hardy and versatile species. It seems to be settling down very well. I understand that the introductions are breeding freely, and that the fish has already begun to appear in the commercial catches. Another tough and versatile *Tilapia*, *T. nilotica*, has been introduced, but it is too early to say whether it has established itself. It would be surprising if it failed to do so. The third is *T. leucosticta*, which appears to be breeding in the lake.

I think it fairly certain that these transplantations will maintain or increase the supplies of fish from Lake Victoria.

Then there is Lake Nakivali, in Uganda. This is a lake of some 10 square miles; until 1934 it was virtually barren, producing only small quantities of *Clarias*, the mud fish. In 1934, and again in 1939, *Tilapia nilotica* were stocked in the lake. By 1942 they were well established, and the Uganda Game and Fisheries Department encouraged a group of Africans to settle on the lake, and instructed them in fishing methods. A good road was made to connect the lake with the highways of Uganda and three model fishing villages were built. Now, with the numbers of fishermen controlled, and the lake in full production, the annual catch of fish is nearly six hundred tons, and at a rate of 60 tons per square mile, or 210 lb. per acre per annum, must be one of the most productive waters in the whole of Africa. Here we have the case of the creation of a new fishery, and an important one.

In a much smaller way, dam and pond stocking can play a useful part in increasing

fish supplies. Take the case of the reservoirs of the Trinidad Leasehold's great oil refinery at Pointe à Pierre. These contained no useful fish at all. In 1950 the first fingerlings of *T. mossambica* were stocked in these reservoirs. There seemed to be no result, until, in 1952, a small boy caught a *Tilapia* in one of the reservoirs which weighed a pound and a half. Since then, the reservoirs have been fished with wire traps, and may soon be producing 1,000 lb. of fish per month: this in a reservoir of some 200 acres, which cannot be treated in any way because the water is required for technical use in the oil refineries.

An interesting by-result of the stocking of dams in Trinidad has been the escape of these fish into the brackish water Caroni Swamp. They appear to be well established now, and there is already a useful cast-net fishery for them.

A final example of pond stocking will now be given. The same useful fish, *T. mossambica*, was introduced into the freshwaters of Jamaica in 1950. There are many ponds and reservoirs in Jamaica, and the freshwaters are very rich in lime. When I visited the island in 1954, I showed the fisheries people how to sex the fingerlings of this species, and a large number of ponds have been stocked with males only. Not only is the male the faster growing sex, but by stocking only males, breeding and subsequent over-population and runting is prevented.

Some remarkable results have been obtained. In the ponds among the sugar-cane fields, male fish have grown from a length of 8 cm. to over 40 cm. and a weight of nearly 5 lb. in 18 months. I think it very probable that this fish, stocked in this way, will make an important addition to the protein supplies of Jamaica, where this is a serious problem, within the next few years. The sexing of the fingerlings, of course, has to be done with great care; on the other hand, it is easy, even for unskilled people. At Malacca, in Malaya, we have just opened a new research station to study and improve the culture of fish for human consumption. The results will be applicable to all tropical territories.

Turning aside from transplantation and dam stocking as a development to increase fish supplies, I will say something about the lake fisheries. Nylon gill-nets are more effective for catching fish than nets made from natural textiles, and the use of nylon gill-nets is rapidly spreading; for example, on Lake Victoria and Lake Mweru in Rhodesia. On Lake Mweru, again, small planked boats are being introduced in place of the much less stable dug-out canoes, and many of these planked boats are fitted with outboard engines, which much increases their radius of action, and so their catches. Outboard engines are also being installed in large numbers on Lake Victoria.

Lake Albert has so far been fished only along the shores, and in shallow water. But exploration, in the first instance by echo-sounder, has shown that there are important stocks of fish in the deeper waters of the lake. Now, planked boats of some size are being built, which may take engines, and these should be able to exploit these new fish stocks. Luckily, the new railway which was completed last year from Kampala to Kasese, may help the distribution of increased catches from Lake Albert. In Lake Victoria, as well, a fishery survey of deeper waters than the present canoe fishermen work has been started, which again aims at bringing into use resources not at present exploited. I am certain, however, that such a survey must be paralleled by a programme of development of more substantial fishing craft than the present open canoes, which remain open canoes even when fitted with outboard engines.

But, naturally enough, the best prospects for fishery development are in the sea fisheries. I have only the time left to give a few examples.

Hong Kong is one of the largest fishing ports in the world, with some 10,000 fishing craft of various types, manned by some 60,000 fishermen. When I visited Hong Kong in 1947, there were no power-driven fishing vessels, and all depended on sail and oars. In 1948, the first two of these vessels were fitted with diesels.

A loans scheme was started, to assist in mechanisation. Now, there are 1,200 power-driven fishing craft, which are so effective that, though they amount to only 10 per cent of Hong Kong's fishing fleet, they land 60 per cent of the catch, and have played the most important part in tripling the supplies of fish in the last few years.

The building of a fine new fish market, on land reclaimed from the sea, has also been a powerful help in the rapid development of the fishing industry that has there occurred. It is as up to date a fish market as any I have seen.

In Hong Kong also, there is a valuable oyster fishery in Deep Bay. The oysters are hardly cultivated, except by spreading shell over the bottom for the settlement of spat. Now, the Hong Kong Fisheries Department and Fisheries Research Unit are introducing the hanging method, by which the oyster-shell spat-collectors are hung on wires from bamboo frames. When they have collected enough spat, they are re-hung on the wires, but now with bamboo distance-pieces between them, so that the oysters can grow without overcrowding. In this way, the oysters can use the whole water column for filtering their food, and it is found in fact that they grow much more rapidly than those which develop from spat settled on shell on the bottom. The work is being watched by the local oyster men, and could lead to a great increase in oyster production. Moreover, transplantation experiments are under way to establish oysters in Tolo Harbour, a large bay of shallow water on the eastern side of the New Territories of Hong Kong.

I will take another example, namely, the north-eastern States of the Federation of Malaya, namely, Kelantan and Trengganu. These States are almost wholly Malay, and were regarded as the stronghold of conservatism in Malay fishing methods. When I visited these States four years ago, all the fishing craft were propelled by hand or sail, and very picturesque they looked, with their brightly painted hulls and the grotesque and handsome carvings on their boom rests. But in the intervening four years there have been two major changes. Outboard and in many cases inboard, diesel engines have been installed in a great number of these fishing crafts, which use a kind of Danish seine, hauled by hand, the fish being located by an expert diver who listens for the fish. They may also use a big lift net, to capture fish which have been caused to shelter beneath and around an artificial structure of palm leaves.

Since 1953, however, a type of diesel-engined fishing boat has been designed, by the staff of the Malayan Fisheries Department, and no fewer than 200 of these have been built in the four years since. They keep some of the features of the sailing craft, especially the high stem and sternposts, and some of the carved work; but they have the engine in a small deckhouse amidships, and seem to be good sea boats. They have a long range, and do long-lining and fish trapping well out into the China Sea, so exploiting a new and much wider range of fishing ground. The fish market at Kuala Trengganu is a fine sight as these boats bring in their catches.

I will give a further example, that of Barbados. Here, also, there has been a revolution in the fishing fleets since 1954. At the time of my visit there, there were only six motor fishing boats, the rest of the fleet of 500-odd being sailers. Very nice boats they are, too, fast and shapely like little yachts. But now, only three years later, there are over 260 motor boats, and only a dwindling 60 sailers. It is in fact becoming difficult to find crews for the sailers.

There is surely little need for me to stress the superiority of the diesel-engined boat over the sailing-boat. The fact that all over the world the sailer is giving way to the power-driven boat speaks for itself. But on the Barbadian scale, the advantages are independence of wind and current, a faster passage out and home, greater ease in handling the gear, chiefly flying fish nets, but also, in the off-season, fish pots and long-lines, and greater comfort for the crew. It is also found that the

catch of the motor boats is much superior to that of the sailing boats, from twice to as much as five-fold.

Ghana, lately the Gold Coast, is also training their fishermen to use small motor trawlers, and then assisting them with loan funds to get such inshore trawlers on hire-purchase. The canoes in use hitherto are sailed and paddled; they do reasonably well with hand lines in the deep water, but the trawlers do better on a year-round basis. There are now about 40 of these small but efficient trawlers at work. They have either a 22 h.p. diesel or a 15 h.p. heavy duty petrol-paraffin engine.

Finally, I will say something about the latest development scheme, namely, a trawling survey of the continental shelf off British Guiana. I had the pleasure of doing the first two voyages, and of planning the campaign. It seems that already results have been encouraging enough to show the way to a small but useful trawling industry. It is realised that, sooner or later, these development schemes will come up against the problem of over-fishing; and the more efficient they become the sooner the problem will arise. Therefore, we have a number of research stations studying the productivity of the sea and lakes in tropical territories.

The distribution of the increased quantities of fish to be expected from all these schemes requires the wholesale fish merchant, the man with some capital who will buy the fish in bulk, and distribute through his own agents. At present, distribution is generally geared to the small hawker who buys small lots. That would serve when catches were small, but will not do when catches become big. My own view is that this will sort itself out. Sooner or later, heavy catches will bring prices down to the point where some smart man will buy in bulk, hire transport, and distribute at a handsome profit; and others will follow suit. Already in Jamaica, for example, a private wholesale fish merchant has set up a refrigerated store, and distributes from there. In British Guiana, several shops have refrigerated fish display cabinets. In Aden, merchants are sending lorries to buy the fish in quantity from the boats; and so it goes on. There is a strong tendency for fish to be sold fresh, rather than salted and dried as formerly. Fresh fish, of course, are more valuable than dried fish; the increasing availability of ice, and improved transport, make the distribution of fresh fish possible in a way impossible a few years ago. It is a trend to encourage.

Mechanisation, moreover, has another very great economic and social advantage. Owners of power-driven fishing boats, with their great radius of action and cheapness of operation, will often find it pays to carry their fish to some convenient market, rather than to land it at their own beach. This trend will inevitably give rise to the fishing port, some point where better shelter, or better communications, or both, make it especially advantageous to land fish. But when fishing ports arise, it becomes possible for many amenities to be developed, for example, ice factories and cold stores, proper fish markets, slipways and engineering shops, stores of fuel and fishing gear. An industry becoming concentrated in this way is in a much better position to go ahead, than one in which the fishermen are scattered in small, poor units along a long stretch of coastline.

WILLIAM ROWAN HAMILTON[1]

by

Dr. A. J. McCONNELL

Introduction

Some years ago Professor Schroedinger made to the Royal Irish Academy in Dublin a communication that gave every promise of being of the highest importance to the scientific world—the solution of one of the outstanding problems of present-day physics, namely, the unification of the gravitational, electromagnetic and mesonic fields in the geometrical framework of relativity theory. The American magazine *Time* reported the announcement in its usual sensational terms, giving Schroedinger's formula, and stating blandly that the communication was made 'in unscientific Dublin, of all places'. No Irishman worthy of the name could allow that slight to pass unnoticed, and a distinguished Irish mathematician, himself resident at that time in America, replied to *Time* in its own language:

> Your reporter on Schroedinger needs a swift kick in the pants. The illustration of Schroedinger's formula at the page-top tells all—a new message in words old but not outworn. The mathematician reads it as follows: Schroedinger bases his new theory on Hamilton's Principle, using as Lagrangian the square root of the determinant of the Ricci tensor. Never mind now about Lagrange and Ricci. But who was this Hamilton ? Born, lived and worked all his life in unscientific Dublin, of all places!

I quote this incident because it gives an excellent illustration of a typical feature of practically all the great advances made in theoretical physics during the present century. It is difficult to think of a single advance that has not been based fundamentally on the mathematics invented by this Irish mathematician, William Rowan Hamilton, who was born in Dublin 152 years ago and lived the whole of his life of 60 years in his native city. There is no other mathematician, the spirit of whose mathematics has impregnated modern physical theory more fully than Hamilton's, and no one deserves more the title of the 'father of modern theoretical physics'.

The Scientific Background of Hamilton's Early Years

To appreciate properly the significance of any great scientific figure, it is necessary to get a picture of the scientific background in which he grew up. For this reason it is important to realise that Hamilton was born on the eve of a revolution in the mathematical worlds of Cambridge and Dublin, a revolution that was to have an incalculable effect on Hamilton's development and was to lead to the most glorious period in the scientific life of Trinity College, Dublin.

In 1812, when Hamilton was seven years old, Bartholomew Lloyd became Professor of Mathematics in Trinity College. This remarkable man immediately introduced the most drastic reforms in the mathematical studies of his university. To understand the nature and extent of the changes made, we must go back for over a hundred years to the end of the seventeenth century. In 1685 Newton published his epoch-making *Principia* in which he expounded his theory of gravitation. To develop his ideas Newton had to invent a new method, which he called the Method of Fluxions, but which is now known as the Differential and Integral Calculus. Unfortunately he clothed his new methods in the geometrical form that had been traditionally handed down from the Greeks. A few years later Leibniz

[1] Address delivered to Sub-Section A* (Mathematics) on September 9, 1957, at the Dublin Meeting of the British Association.

independently invented the same calculus with a different notation and on a more analytical basis. The rivalry between the adherents of the two systems led to one of the fiercest and bitterest controversies in the history of science; the British and Continental mathematicians were divided into two opposing camps, each violently supporting the claims of their respective champions. The controversy was disastrous for mathematics in these islands, for, as it happened, Leibniz's method proved far superior to Newton's, with the result that, while mathematical studies stagnated in England for over a century, on the Continent enormous progress was achieved in the new analytical processes by men like the Bernoullis, Euler and Lagrange.

The foundation of the École Polytechnique at the end of the century brought together as its professors the most brilliant mathematicians of the day, Lagrange, Laplace, Fourier, Poisson, Monge, Legendre; and a series of excellent text-books based upon their lectures began to appear. When these found their way to Cambridge and Dublin, the effect produced could well be compared to the bursting of a dam. In Dublin one man alone, Bartholomew Lloyd, conceived and executed the most important and rapid revolution ever effected in the academic studies of a university. The new French text-books were introduced into the courses, and new ones were written to meet the demand for instruction in the Continental methods. One has only to read these books to feel the atmosphere of enthusiasm in which they were produced. To quote from a text-book of the period (Lardner, *Elements of the Theory of Central Forces*, 1820)—'By the impulse which it thus received, the study of mathematics has leaped a chasm of a hundred years, and men who, according to the system pursued two years before the advancement of Dr. Lloyd to the Professorship of Mathematics, would be employed in fathoming the mysteries of Decimal Fractions, are rather more respectably employed with the *Mécanique Céleste*'.

Hamilton's Early Education

William Rowan Hamilton was born in 1805, the son of a Dublin solicitor. His father was a man of ability in his profession, but (according to a contemporary record) 'a man of exuberant eloquence and convivial disposition', which traits were indeed inherited to some extent by his brilliant son. Indeed, it was said of him that he managed well everyone's financial affairs except his own, and as a consequence the family fortunes oscillated between prosperity and bankruptcy.

However, the young Hamilton's development owed little to the influence of his parents, for at the tender age of three he was entrusted to the care of his father's elder brother, who was a graduate of Trinity College, a sound classical scholar, and the headmaster of a small private school at Trim, a town about 25 miles north-west of Dublin. This uncle, who was henceforth to have complete control of his nephew's early education, had most decided ideas on what constituted a sound educational policy. He believed in a thorough grounding in languages, ancient and modern, before any mathematics other than a little arithmetic was introduced. His pupil proved to be amazingly precocious. At the age of three he was a superior reader of English and was considerably advanced in arithmetic; at four he was a good geographer; at five he read and translated Latin, Greek and Hebrew, and he loved to recite Dryden, Milton, Collins and Homer—the last in Greek; at eight he had added French and Italian to his collection and extemporised freely in Latin hexameters; at nine he was laying a foundation in Oriental languages by studying Arabic, Persian and Sanscrit. His father writes of him before his tenth birthday:

> His thirst for the oriental languages is unabated. He is now master of most, indeed of all except the minor and comparatively provincial ones. The Hebrew, Persian and Arabic are about to be confirmed by the superior and intimate acquaintance with the Sanscrit, in which he is already proficient. The Chaldee and Syriac he is grounded in, and the Hindoostanee, Malay, Mahratta, Bengali and others. He is about to commence Chinese, but the

difficulties of procuring books is very great. It cost me a large sum to supply him from London, and I hope the money was well expended.

The amazing thing is that, with this extraordinary upbringing, Hamilton appears to have been in other respects a normal, high-spirited schoolboy, fond of outdoor sports, which in his case consisted chiefly in running and swimming.

Not until he was ten was Hamilton introduced to Euclid, which he quickly devoured; and from this point his mathematical education progressed with leaps and bounds. At fifteen he was reading Newton's *Principia*, and soon after he was studying the French text-books that were already in the curriculum of the university. Hamilton quickly realised that he had met his fate. In a letter written to an aunt at the age of sixteen he says:

I have been continuing my Classics, but I fear that I shall never again be so fond of them as of the Mathematics that I am now reading. Who would not rather have the fame of Archimedes than that of his conqueror Marcellus or than any of those learned commentators on the Classics, whose highest ambition was to be familiar with the thoughts of other men ? Mighty minds in all ages have combined to rear upon a lofty eminence the vast and beautiful temple of science and inscribed their names upon it in imperishable characters: but the edifice is not completed. It is not yet too late to add another pillar or another ornament. I have yet scarcely arrived at its foot, but I may one day aspire to reach the summit.

At sixteen he was reading Laplace's *Mécanique Céleste* and discovered an error in Laplace's proof of the parallelogram of forces. Other books he mentions as having read are Lagrange's *Calcul des Fonctions* and *Théorie des Fonctions Analytiques*, and Monge's *Applications de l'Analyse à la Géométrie*. Many years later he wrote to Tait:

I think it was about the age of sixteen or seventeen that I was carried away by the attractions of the French School and especially by those of Lagrange. The *Calcul des Fonctions* charmed me and for several years I supposed it to be, not merely an elegant and original production of a genius whose mathematics almost sublimated into poetry, but a sound and sufficient basis of the Differential Calculus.

Ten years later, when he was writing his preface to his famous *First Essay on Dynamics*, he refers to Lagrange's *Mécanique Analytique* as 'that great scientific poem'.

Hamilton entered Trinity College, Dublin, in 1823, and carried everything before him both in classics and mathematics. In the university at this time there were a number of fine mathematicians, all well-versed in the French mathematics (as they were then called)—Bartholomew Lloyd, John Brinkley, Henry Harte, Romney Robinson, Thomas Luby and Dionysius Lardner. All of these men were authors of excellent text-books and were able to give the young Hamilton that stimulus of personal contact that he required. At any rate, as early as 1824, at the age of 19, he had started his career as an original mathematician. He writes: 'In optics I have made a curious discovery, or so it seems to me.' This work developed into a paper in Caustics, which was presented to the Royal Irish Academy the same year. It was never actually published until his *Collected Works* appeared in 1931; but it formed the nucleus of his famous series of papers on *Systems of Rays*, which were published in 1827.

Life at Dunsink and Literary Associations

When Hamilton was in his last year in College, the Andrews Professorship of Astronomy, and with it the post of Astronomer Royal of Ireland, became vacant. Several well-known astronomers were candidates for the post, including Airy, who afterwards became Astronomer Royal of England, but the young undergraduate of twenty-one was appointed to the Chair.

As Astronomer Royal Hamilton was obliged to reside at the Observatory at Dunsink, which is about six miles from Dublin, and his duties in Trinity College consisted in giving only two lectures per week during Michaelmas Term. This meant that he was largely cut off from the distractions associated with routine teaching and administration, which was, of course, all to the good so far as Hamilton's work was concerned. Einstein on one occasion remarked that the ideal post for a young theoretical physicist was that of lighthouse-keeper on a lonely coast; the next best was that of Astronomer Royal at Dunsink at the beginning of the nineteenth century. But this isolation was not so fortunate for the College, for it meant that Hamilton never built up a school of young workers round him, and in actual fact his mathematical work had almost a negligible effect on the studies of his own university during his lifetime.

Hamilton was to spend the rest of his life at Dunsink, a life that was to be on the whole quiet and uneventful, a manner of life that was largely forced upon him by its isolated position. For Hamilton was essentially a very sociable person, who delighted in the company of his fellows and in good conversation. He was, of course, a man of wide culture, well-read in the classics and in the literature of modern Europe. He was deeply interested in philosophy, and particularly admired the systems of Berkeley and Kant, as indeed every mathematician must. Moreover he was not one of those who are said to be without honour in his own country. Far from it. Probably no man received greater and more prompt recognition of his great gifts, and he was much sought after by all classes of society. On the occasion of the visit of the British Association to Dublin in 1835, Hamilton was knighted at a reception held in the great hall of the Library of Trinity College, in recognition of his already eminent scientific achievements.

Not only was he from the first regarded as the leading scientific figure of the day, but he was also well-known in literary circles. He was a close friend of Wordsworth, Coleridge, Maria Edgeworth, Felicia Hemans and Aubrey de Vere. With them all he exchanged visits from time to time, and carried on an extensive correspondence. The fact is that Hamilton had literary as well as scientific ambitions, and he wrote many poems, most of which he submitted to Wordsworth for criticism and advice, in spite of a distinct lack of enthusiasm on the part of the older man. Indeed, it was as a result of a visit paid by Wordsworth to Dunsink in 1829 that Hamilton was led to the conclusion that 'for him the future path must be the path of Science, and not that of Poetry; that he must renounce the hope of habitually cultivating both, and that therefore he must brace himself to bid a painful farewell to Poetry'. Actually, it was only a reluctant *au revoir* that he had said, for he continued to turn out verses all his life. Quite a lot of Hamilton's poetry was called forth by that weakness common to both scientists and poets alike—love. He had indeed two severe disappointments in love before he finally married at the age of 28, and the subjects of his verses change. Some of you will recall the advice of Lord Chesterfield to his son always to flatter a great man on that accomplishment at which he is second best; and I am quite sure that a more rapid road would have been won to Hamilton's heart by praising his literary rather than his scientific efforts. Nevertheless the truth is that all his poetic compositions, with I think one exception, have been not undeservedly buried and forgotten.

Geometrical Optics

It is time to turn to an account of Hamilton's scientific work. Like his great predecessor Newton, it was in Geometrical Optics that his first great discoveries were made. We have seen that he had already done valuable original work on caustics as an undergraduate. He spent the next three years in developing the results of this first investigation, and in 1827, the year of his election to the Andrews professorship, he published his *Systems of Rays*.

To get some idea of what he succeeded in doing, it is necessary to say something of the state of knowledge of optics at that time. Geometrical optics is the branch of optics that deals with those properties of light-propagation which do not involve the phenomena of diffraction and interference; and we now know that it represents that approximation to truth which is obtained by neglecting the wave-length of light. At least one hundred and fifty years before Hamilton, the fundamental law or principle forming the basis of geometrical optics had been discovered by Fermat—the Principle of Least Time. This stated that a ray of light passing from a point A to a point P in any medium will follow the particular path for which the time of passage is the least possible. Mathematicians had already devised an elegant method (the Calculus of Variations) by which from this principle the differential equations of the path of light could be found; these equations had then to be integrated to find the actual optical path from A to P. Hamilton discovered that, if the actual time of passage from A to P is expressed as a function of the extremities A and P of the path, this function can be used directly to obtain the path without any integration at all. Moreover, he found that this same function, which he called the Characteristic Function, could be itself calculated by means of a certain partial differential equation, when we know the medium through which the light is passing. The main properties of this characteristic function Hamilton developed in a series of papers during the years 1827–32. He had in fact succeeded in expressing the whole of geometrical optics in one all-embracing central relation. His theory had an immediate and spectacular success. In his final paper of 1832 Hamilton applied his results to Fresnel's theory of the double refraction of light in biaxial crystals, and deduced theoretically that for certain directions of the incident ray the light would be refracted as a cone of rays inside the crystal—a totally unexpected result. He asked his friend Humphrey Lloyd, the son of Bartholomew and the then Professor of Physics, to test the result experimentally, and the phenomenon of conical refraction was observed for the first time in December 1832. This was the first of four famous predictions of physical phenomena by purely theoretical calculation, the other three being the discovery of Neptune by Adams and Leverrier in 1845, by analysing the perturbations of Uranus, the theoretical prediction of wireless waves by Maxwell in 1864, afterwards verified experimentally by Hertz, and lastly Einstein's deduction of the bending of light rays by the sun from his theory of relativity, later observed during the solar eclipse of 1919.

I should say something at this stage of the manner in which Hamilton worked, for reading his published papers would create a totally false impression. Preserved in the Library of Trinity College are about 250 closely written notebooks of varying sizes, much of the matter of which had never been published until recently. A perusal of these notebooks shows clearly that Hamilton reached his general theorems by the tedious working out of example after example, each a more general case than the preceding, until from generalisation to generalisation he reached his final result, which he then published in an extremely condensed and elegant form. It was not that Hamilton did not perceive the end at which he was aiming, but he was determined to test patiently all particular cases before he was satisfied with the general result. To illustrate the immense amount of labour he was prepared to give to the perfection of his work, I may say that he wrote out the last paper on the *Systems of Rays*, which runs to 130 quarto pages of the *Collected Works*, ten times before he was satisfied with the final draft; and he never hesitated to undertake the most laborious calculation necessary to verify any detail of his investigations.

Dynamics

Hamilton at once realised that the method that he had discovered in geometrical optics could be applied equally well to dynamics. For there is a principle in

dynamics which is exactly similar to that of least time in optics—the Principle of Least Action. This states that a body, which is moving from a position A to a position P under the action of given forces, will move along that path which makes a certain quantity, called the action, the least possible. In other words, the whole mathematical theory of geometrical optics is translated into that of dynamics by replacing the time of the optical path by the action of the dynamical path. In Fig. 1

Geometrical Optics

Fermat's Principle of Least Time:

$$\delta \int \mu \, ds = 0 \quad (\mu = \text{refractive index})$$

Hamilton's Characteristic Function:

$$W(x,y,z,a,b,c) = \int_A^P \mu \, ds$$

Optical Path:

$$\frac{\partial W}{\partial a} = a', \quad \frac{\partial W}{\partial b} = b', \quad \frac{\partial W}{\partial c} = c'$$

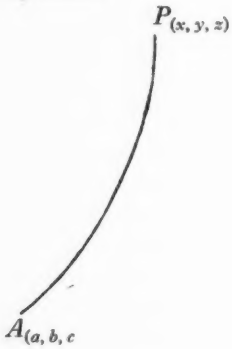
Hamilton's Partial Differential Equation:

$$\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2 = \mu^2$$

Time-free Wave Equation of Physical Optics:

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = -4\pi^2 v^2 \mu^2 \phi$$

Dynamics



Maupertuis' Principle of Least Action:

$$\delta \int \sqrt{2m(E-V)}\, ds = 0 \quad \begin{pmatrix} V = \text{potential energy} \\ E = \text{total energy} \end{pmatrix}$$

Hamilton's Characteristic Function:

$$W(x,y,z,a,b,c) = \int_A^P \sqrt{2m(E-V)}\, ds$$

Dynamical Path:

$$\frac{\partial W}{\partial a} = a', \quad \frac{\partial W}{\partial b} = b', \quad \frac{\partial W}{\partial c} = c'$$

Hamilton's Partial Differential Equation:

$$\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2 = 2m(E-V)$$

Time-free Schroedinger Equation of Quantum Theory:

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = -\frac{4\pi^2}{h^2} 2m(E-V)\phi$$

Figure 1.

will be found the corresponding formulae showing clearly the complete correspondence between Hamilton's results in optics and dynamics. This work appeared in the *Transactions of the Royal Society of London* in 1834–5, and it became one of the great corner-stones of theoretical dynamics. His dynamical researches brought him immediate world-wide fame, but the full significance of his work was not realised until, within the last thirty years, the advent of the new quantum theory showed how deeply Hamilton had dug. One has only to glance at Hamilton's equation and Schroedinger's wave equation to see that Hamilton's theory of dynamics is related to wave mechanics in exactly the same way that geometrical optics is related to physical optics. If only experimental physics had been more fully developed, the step from Hamilton's dynamics to wave-mechanics was already there to be taken a hundred years earlier.

Hamilton realised very soon that this method, which he had developed for optics and dynamics, could be used in any theory for which a variational principle could be formulated. It was his intention to publish a book called *The Calculus of Principal Relations*, in which the method was to be extended and applied as a branch of the calculus of variations. Unfortunately, the only parts that remain of this book among the Hamilton manuscripts consist of the introduction and half of the first chapter. But enough survives to show that he had obtained two interesting methods of approximating to his Characteristic Function, and also that he had anticipated Rayleigh in discovering the method of approximation that is nkown today as Rayleigh's Principle.

During the next four years (1835–9) Hamilton continued a series of investigations on the Dynamics of Light, that is, the mathematical theory of light-propagation regarded as produced by the oscillations of particles forming an elastic body. These papers, published for the first time in the second volume of the *Collected Works* (1940), will repay the attention of the pure mathematician, for in them he develops very interesting analytical methods. He uses operational methods freely and anticipates Heaviside's operator; and he was the first to distinguish clearly between group-velocity and phase-velocity, a result which is usually ascribed to Rayleigh. These researches also led him to an examination of the analytical representation of certain types of functions, involving a generalisation of Fourier's celebrated theorem; these results he published under the title of *Fluctuating Functions*. He also obtained asymptotic expansions of Bessel functions, which appeared in his researches on the dynamics of light and darkness.

Algebra and Quaternions

We come now to Hamilton's second outstanding contribution to mathematics, his discovery of quaternions.

It would be a mistake to suppose that Hamilton concentrated on one subject at a time to the exclusion of all others; he usually had several investigations on the stocks at once. As early as 1828 a long correspondence on algebra had been started with John Graves, a college class-mate and one of three brothers with whom Hamilton maintained a close friendship all his life. The second brother, Charles, was a Fellow of Trinity, Professor of Mathematics, and later Bishop of Limerick, and the third brother, Robert, became Hamilton's biographer. It was John Graves more than anyone else who kept Hamilton's interest in algebra stimulated from time to time, an interest that led directly to the great discovery of 1843. Graves was resident in England, where algebraic studies were being actively pursued at this time, and he became Professor of Jurisprudence in University College, London, to which he bequeathed his magnificent mathematical library of 10,000 volumes.

Hamilton's interest in algebra was first aroused by the old problem of the so-called imaginary numbers, the problem of the square root of -1, which had been

such a stumbling block to generations of students. Complex numbers of the form $a+\sqrt{-1}\,b$, where a and b are ordinary numbers, were known for many years as the roots of certain quadratic equations and were found to be of immense value in dealing with important processes in analysis. Up to the beginning of the nineteenth century mathematicians used these complex numbers freely in a purely mechanical way to produce new results, but the methods involving their use were regarded as very questionable, since no reasonable meaning could be assigned to a symbol such as $\sqrt{-1}$. In 1828 there appeared in England Warren's book, *On the Geometrical Representation of Imaginary Numbers*, describing the now well-known method, due to Argand in 1806, of representing a complex number geometrically as a directed line in a plane. This method placed the theory on a sound geometrical basis, and is the treatment usually given in elementary text-books on algebra and trigonometry. Hamilton, who always preferred analysis to geometry, found that a logical algebra of complex numbers could be developed by regarding these new numbers as *pairs* or *couples* of ordinary numbers, and he presented these ideas in 1833 in a paper called *The Theory of Algebraic Couples*. In this paper Hamilton was the first to give a purely algebraic theory of imaginary numbers as number-couples. Once addition and multiplication of such number-pairs were defined, the rest followed logically from the well-known laws of algebra, which these couples satisfy.

In characteristic fashion, Hamilton proceeded to inquire if it would not be possible to generalise this theory. So he started to search for an algebra of *number-triads* or *triplets*, as he called them; that is, he looked for generalised numbers of the form (a, b, c),where a, b, c are three ordinary numbers. For almost ten years he carried on this search, in which he was joined by John Graves and Augustus de Morgan. The search for a triplet algebra that would satisfy the fundamental laws of algebra was a complete failure, and indeed we know now that a solution does not

Algebra of Number-Couples: (a,b)

Definitions of Addition and Multiplication:

$$(a,b)+(a',b') = (a+a', b+b'),$$

$$(a,b)\times(a',b') = (aa'-bb', ab'+ba').$$

If $(1,0) = 1, \quad (0,1) = i, \quad$ then $i^2 = -1;$

and $(a,b) = a(1,0)+b(0,1) = a+bi.$

Algebra of Quaternions: (a,b,c,d)

Definitions of Addition and Multiplication:

$$(a,b,c,d)+(a',b',c',d') = (a+a', b+b', c+c', d+d'),$$

$$(a,b,c,d)\times(a,'b',c',d') = (aa'-bb'-cc'-dd', ab'+ba'+cd'-dc',$$
$$ac'-bd'+ca'+db', ad'+bc'-cb'+da').$$

$$[(a,b,c,d)\times(a',b',c',d') \neq (a',b',c',d')\times(a,b,c,d).]$$

If $(1,0,0,0) = 1, \quad (0,1,0,0) = i, \quad (0,0,1,0) = j, \quad (0,0,0,1) = k,$

then $$i^2 = j^2 = k^2 = -1,$$

$$jk = -kj = i, \quad ki = -ik = j, \quad ij = -ji = k;$$

and $$(a,b,c,d) = a(1,0,0,0)+b(0,1,0,0)+c(0,0,1,0)$$
$$+d(0,0,0,1) = a+bi+cj+dk.$$

Figure 2.

exist. In 1843 Hamilton made the great discovery that he could get such an algebra of quadruplets, and not triplets, but only if he dropped the commutative law of multiplication, retaining all the others. This was indeed an extraordinary discovery, since up to that time no one had even dreamed of denying any of the God-given laws of algebra. The idea that there could be numbers for which ab was not equal to ba represented a step that only a genius would dare take. Hamilton was prepared to take that step, and in so doing revolutionised the whole of algebra. Nowadays mathematicians are quite prepared to deny any of the laws of algebra, but it was of course the first step that counts. (See Fig. 2.)

These quadruplets Hamilton called quaternions, and as in the case of couples, it was the definition of multiplication that gave all the difficulty. Once that was solved, all the rest followed straightforwardly. This aspect of quaternions is the algebraic aspect, and is the natural extension of Hamilton's theory of couples. But, as in the case of complex numbers, there is also a geometrical aspect. As we have said before, complex algebra can be considered geometrically as dealing with directed lines or vectors in a plane, and a complex number can be regarded as an operator that turns one vector in a plane into another vector in the same plane. So, too, quaternion algebra can be regarded geometrically as the algebra of directed lines, or vectors, in space, and a quaternion can be regarded as an operator that turns one vector in space into another vector in space. The two ways of looking at quaternions are mathematically equivalent, and Hamilton was fully aware of both aspects at the time of the discovery.

Hamilton has left a dramatic record of the discovery of quaternions which is of great interest both from the human and scientific points of view. In a letter to his son Archibald, written just before his death twenty years later, he says:

> In October, 1843, having recently returned from a meeting of the British Association in Cork, the desire to discover the laws of the multiplication of triplets regained with me a certain strength and earnestness, which had for years been dormant, but was occasionally talked of with you. Every morning in the early part of the above-cited month, on my coming down to breakfast, your brother William Edwin and yourself used to ask me, 'Well, Papa, can you *multiply* triplets?' Whereto I was always obliged to reply, with a sad shake of the head, 'No, I can only *add* and subtract them'. But on the 16th day of the same month—which happened to be a Monday and a Council day of the Royal Irish Academy—I was walking in to attend and preside, and your mother was walking with me, along the Royal Canal, to which she had perhaps been driven; and although she talked with me now and then, yet an under-current of thought was going on in my mind, which gave at last a result, whereof it is not too much to say that I felt at once the importance. An electric current seemed to close; and a spark flashed forth, the herald (as I foresaw immediately) of many long years to come of definitely directed thought and work, by myself if spared, and at all events on the part of others, if I should ever be allowed to live long enough distinctly to communicate the discovery. I pulled out on the spot a pocket-book, which still exists, and made an entry then and there. Nor could I resist the impulse—unphilosophical as it may have been—to cut with a knife on a stone of Brougham Bridge, as we passed it, the fundamental formula with the symbols i,j,k:
>
> $$i^2 = j^2 = k^2 = ijk = -1,$$
>
> which contains the solution of the Problem, but of course, as an inscription, has long since mouldered away. A more durable notice remains, however, on the Council Books of the Academy for that day, which records the fact that I then asked for and obtained leave to read a Paper on Quaternions, at the First General Meeting of the Session; which reading took place accordingly on Monday the 13th of the November following.

Last Years

Hamilton spent the last twenty-two years of his life in developing this new and strange algebra. The scepticism with which Quaternions were received by the

mathematical world led Hamilton to prove that he really had discovered one of the most powerful instruments in applied mathematics, and he showed that Quaternions could be used to give a most elegant treatment of Statics, Dynamics, Wave Theory, Potential Theory, Differential Geometry; in fact, of every known branch of applied mathematics. Indeed, if he had been alive today, he could have shown that it was also an ideal instrument to deal with Dirac's theory of the electron and Einstein's special theory of relativity. The importance of Hamilton's discovery of a non-commutative algebra need not be emphasised to the modern physicist, who is familiar with the $pq-qp$ of Dirac.

Towards the end of his life, Hamilton's habits became more and more irregular. His best friends had either died or left Dublin, and relations with his wife had for some years been strained. So he turned to his beloved mathematics for consolation. He would work for hours in his study, paying no attention to meals or to reasonable bed-time hours. Sometimes meals were brought into his study, sometimes not; even if they were, he often left them uneaten. He had to get nourishment somewhere to keep going, and he got it mainly from alcohol. His health, of course, gradually gave way under the unnatural conditions in which he was living, and he finally died in August 1865. After his death, his study was found to be filled with books and manuscripts in utter confusion, with plates of uneaten dinners sandwiched in between the mountainous piles of papers.

When we remember that one of the driving impulses behind Hamilton's incessant activity was his desire to put his superb genius to such uses as would bring glory to his native land rather than honour to himself, perhaps I should close with the words that were used prophetically by Charles Graves in the *Éloge* which he delivered to the Royal Irish Academy after his death.

> Believe me, the fame of Sir William Rowan Hamilton will become yet greater when the world has been furnished with materials enabling it more perfectly to estimate the variety and richness of his endowments and the value of the services he has rendered to science. His world-wide reputation warrants us in regarding his name as a glory which is not to pass away from the scientific and literary chaplet of Ireland. I cannot doubt that I have had your sympathy in the expression of my admiration for one who, indeed, as a human being, had his share of human infirmity, but whose nobly countervailing greatness, both intellectual and moral, was such as every Irishman will long love to dwell upon.

CHEMISTRY IN THE SERVICE OF AGRICULTURE

At the Annual Meeting of the Association in Dublin, Section B (Chemistry) and Section M (Agriculture) devoted a joint session on Tuesday, September 10th, 1957, to a symposium on 'Chemistry in the service of agriculture'. The Chairman's introductory paper was given by Mr. A. W. Marsden, XVth International Dairy Congress Secretariat. He was followed by Mr. J. W. Parkes, of W. & H. M. Goulding Ltd., who spoke on the Irish fertiliser industry. The third paper, by Dr. T. Walsh, Irish Department of Agriculture, was on evaluating soil fertility by chemical means, and the last speaker was Dr. P. W. Brian, I.C.I. Ltd., who gave an interesting discourse on some plant hormones.

The papers, which have been abridged and edited by Mr. A. W. Marsden, appear below.

INTRODUCTION

By A. W. Marsden

In this age when nuclear power, guided missiles, nationalism and the quest for political power seem to be the be-all and end-all, it is often forgotten that man's daily material wants are still quite simple, viz., an adequate supply of water, food, clothing and shelter. These are all provided from the land. In fact, agriculture is still the world's most important and primary industry, with vast amounts of capital and labour employed in raising crops and tending stock. Almost 60 per cent of the human race is engaged on the land; indeed, over 35 per cent are peasants or small farmers in the Far East alone. Unfortunately, this large Asian rural population, together with millions of smallholders in the Near East, Africa and Latin America, generally has the lowest standards of living, and is not able to grow or buy enough even for the bare necessities of life as judged by Western standards. It is a wretched sight, and surely reprehensible of the twentieth century, to see human beings (as can be done in Asia) without sufficient food and clothing, and unable, through ignorance, prejudice or other misfortune, to provide enough food for themselves, their families and their cattle.

The factors involved in this complex problem are many and varied, but, at the core, the troubles seem to revolve round this one point: the available supply of food is not sufficient for a reasonable level of nutrition amongst the present population. To add to the problem, the number of human beings in the world is increasing at an alarming rate. For centuries, wars, famine and disease kept down the population; now it seems that the applications of medical science and modern transport *allow* many more people to remain alive, but the human race is not yet willing to provide itself with enough food and clothing to enable all its members to enjoy a full, useful and happy life.

This raises the question as to whether or not this world will be able and willing to provide enough food for man and beast in A.D. 2000, when the population may be 4,000 or 5,000 million souls. There are many who take the pessimistic view, but I firmly believe that the world *can* feed 5,000 million people. It will need, however, a far greater application of science to agriculture, and in this the chemist is going to be in the forefront.

The theme of the following papers is 'Chemistry in the service of agriculture'. The dictionary gives the word 'service' as derived through the French from two

Latin verbs: *servire*, to serve or attend upon, and *servare*, to save, preserve or protect. These seemed to be very apt descriptions of the relationship of chemistry to agriculture, for the chemist has not only helped or served the farmer in raising his crops and feeding his cattle, but he has also saved and protected many of his crops and stock by providing fertilisers, pest-control chemicals and pharmaceutical products.

In his Presidential Address to the Society of Chemical Industry at its Annual General Meeting in 1955, Sir William Ogg gave an excellent account of the role of the chemist in agriculture. It is probably true to say that agriculture has benefited more from chemistry than from any other science. The reason for this is not hard to find, for the chemist has had at least six roles in agricultural development, as can be seen from the following:

Soils. The chemist has been foremost in increasing our knowledge of the soil, and its relations with the plant. This is of fundamental importance and is the basis of all agriculture. In spite of more than a century's study, since the days of Liebig and of Lawes and Gilbert, we still have much to learn about the soil–water–plant-nutrient–crop relationships. Dr. Walsh will deal with this side of agricultural chemistry in his paper on some aspects of soil fertility.

Fertilisers. The production and utilisation of fertilisers is essential for both healthy and profitable yields of crops. The world still uses far too little of these important chemical materials. They will have to be made in greater quantity and at a price within the reach of the small peasant farmer if the Asian and the African peasant is to benefit. Mr. Parkes's paper is on the growth of the fertiliser industry, with special reference to Ireland.

Pesticides. The control of pests and diseases is now becoming much easier, due in large measure to the availability of many new types of insecticides and fungicides. The introduction of such new concepts as poisons which can be absorbed by the plant, as in systemic insecticides, offers many opportunities for pest control which were previously unobtainable. Chemistry is all-important in this side of agricultural production.

Plant Hormones. The eradication of weeds, both in arable crops and pastures, has until recently been an expensive process both in time and labour. But our greater chemical knowledge of the plant hormones has enabled the farmer to control his weeds by simple applications of the appropriate chemical. Dr. Brian will say something about this fascinating side of the role of chemistry in controlling the growth of plants which are both useful and harmful in agriculture.

Animal Nutrition. An understanding of the feeding of animals has enabled the chemist to advise the stockman on the dietary needs of cattle, and to compound their rations accordingly. More recently, the inclusion of antibiotics in feeds for young stock has opened up an entirely new field in animal nutrition. This is a particularly important aspect of agriculture because of the high nutritive value of animal products as meat and milk.

Primary Products. Lastly, the farmer produces many of the materials which the chemist needs as raw materials in his industry: sugar-beet, oil seeds, rubber latex, cotton lint and flax are but a few of the agricultural products which must be processed chemically before they can be used by the community.

It seems to me that by a continued and even greater collaboration between the chemist and the farmer, we can look forward to the next half-century with every confidence that the world will be better fed and clothed. I do not hold the view that, because the animal is not a very efficient converter of greenstuff into animal protein and fat, we should eat extracted grass protein in places of beef-steak, or drink a vegetable-oil emulsion in place of milk. For a healthy world, and for a thriving farming community in any country, the people must have good food in greater

quantity and variety than at present. By further applications of the chemical knowledge which we now have, to the processes of food production, this can be achieved even in a world with a growing population. The means of increasing the world's agricultural production almost twofold is in our hands today if we want to use it. Given the opportunity, the chemist can serve, save and protect agriculture without recourse to replacing its finest products by substitutes prepared in his laboratories or factories.

THE CHEMICAL EVALUATION OF SOIL FERTILITY

By Dr. T. Walsh

The chemical evaluation of soil fertility presents many complex and difficult problems related to the inherent characteristics of soils, external environmental factors and plant reaction.

Many of the environmental factors, including temperature, radiant energy, humidity, atmospheric composition and biotic, moreover, do not work independently but on the other hand interact with the soil and plant factors to complicate the problem further. As a basis for evaluating soil fertility the study of the various phases of soil development through the medium of soil morphological and genetical studies and the establishment of a proper interpretative system of classification, represents an important advance. The Irish system of soil classification, which is now coming to play an important part as a basis for soil fertility studies, has been developed as a fully interpretative one in terms of practical crop and animal response effects. The major factors in determining soil fertility may be evaluated against a background of (*a*) inherited, (*b*) developed and (*c*) induced characteristics. For instance, through the adoption of this approach it has been possible to classify major groups of soils into various categories in relation to their cobalt-supplying power to herbage, an important consideration in livestock husbandry.

Against this background of research on soils, a Soils Advisory Service, using a chemical evaluation technique, has been built up. Because of the complex nature of soil fertility and of the varying interactions which take place between nutrient elements in the soil, chemical soil tests must be calibrated against crop response through the medium of well-designed field experiments carried out on different soil types. This allows the establishment of growth and crop yield curves related not only to the chemical constitution of the soil and the characteristics of each particular crop but to other environmental factors and varying soil conditions. From the use of such growth curves it has been possible to establish the rational use of fertilisers in terms of yield response and also to evaluate yield response on an optimum economic basis against the nutrient status of the soil as revealed by chemical analysis.

In order to cater for very large demands for specific soil fertility information by farmers, the Soils Advisory Service now operating at Johnstown Castle has been organised on the basis of the use of a mass system of analysis involving up to half a million separate analyses in the year. It is, in fact, one of the major centres for this work in Europe. Because of the seasonal demands on this service, it has been necessary to cater at certain periods for upwards of 5,000 different chemical analyses per day. In carrying out this work a high degree of chemical precision has to be maintained, and to achieve this many modern analytical techniques, including the use of colorimetric, flame photometric and spectographic methods of analysis, are in operation. It must be emphasised that while chemical analysis is an integral part of this service, it is only one phase, the other important phases being sampling and the evaluation of the results, the latter against a background of basic research

information on soil characteristics, farm-produce price factors, and the farmers' financial and other resources. This service is now playing a highly important part in farming activities, having stimulated not only increased fertiliser use but also more efficient fertiliser use in many areas.

This, however, is only one aspect of the chemical evaluation of soil fertility. There are also many other ways in which the chemical approach is contributing valuable information. The practice of liming, due to the segregation of the different factors in the soil acidity complex, is now better understood. The field of soil, plant and animal relationships, involving under Irish conditions the very important factor of efficient livestock production, is also another sphere in which chemistry has in recent years played a particularly important part. Of particular significance has been the establishment of the relationships between cobalt and various pining diseases of sheep and cattle, of molybdenum and copper interactions in relation to hypocuprosis, and of the phosphorus status of soils and herbage in relation to aphosphorosis. Another aspect of this work has been the association of abnormal levels of selenium in soils of pasture herbage with poisonous effects in livestock in certain districts in the country. It can be seen from this also that no longer should we think of soil fertility alone in relation merely to crop response but also in relation to crop quality.

Finally, while recent years have seen the development of much knowledge in soil fertility, its use in practical farming, and the realisation of the hopes of many of the earlier agricultural chemists, much more information remains to be gleaned from the soil by chemical methods.

THE FERTILISER INDUSTRY IN IRELAND

By J. W. Parkes

The British Association for the Advancement of Science has met in Dublin in 1835, 1857, 1878, 1908 and 1957, and it is of interest to trace briefly the developments in the use of fertilisers that have occurred during this time.

In 1835 no reference to fertilisers was made at the meeting, and for all practical purposes the manures used at that time were similar to those described by Richard Kirwan, F.R.S., in his essay to the Royal Dublin Society in 1801. They included various types of marls, chalk, lime, sea sand, farmyard manure, seaweed and turf mould.

About this time crushed bones were beginning to come into prominence. The foundation of the superphosphate industry followed the discovery that the insoluble phosphate in bones could be rendered more readily available to the plant by digesting finely ground bone meal with sulphuric acid.

In the year 1840 Liebig published his report entitled 'Chemistry in its application to agriculture and physiology' and suggested the treatment of bones with sulphuric acid. Although apparently he made no effort to put the idea to practical use himself, his view gained fairly widespread publicity. From the point of view of practical application the honours are shared by James Murray, a physician of Dublin, and John Bennet Lawes. Priority in this connection goes to Murray, while the credit for the successful industrial exploitation of the idea goes to Lawes. Murray took out his patent for the manufacture of superphosphate in 1842. His letter of application for an English patent was dated May 23, 1842, the same day as J. B. Lawes applied for his patent. Prior to this, on May 12, 1842, Murray applied for a Scottish patent. Lawes bought up Murray's patent on or about January 28, 1846, and a letter from Lawes's patent agent, Curling & Hope, states categorically that Murray's was the priority patent.

When the British Association met in Dublin in 1857 the value of water-soluble phosphate had been recognised and the treatment of finely ground bones in sulphuric acid established on a commercial scale. For many years the product obtained from bones was considered superior to that from mineral phosphates due to the presence of organic matter containing nitrogen which was also recognised as an important plant food.

At the 1857 meeting, there were five papers on fertilisers in the Chemistry Section, including one by Murray in which reference is made to the soluble phosphate of lime (vitriolised bones) applied to land near Belfast forty years previously, i.e. in 1817, which yielded luxuriant pastures. Also at the meeting in 1857, Murray showed some of the double phosphate of ammonia and magnesia artificially prepared as a fertiliser, which must have been one of the earliest compound manures prepared. He patented the compound and formed a company to develop it, but without success.

To some it may appear strange that Murray did not make more of a success of his fertiliser business, but during the important years around 1840, Murray, in addition to a considerable private practice, had two official State appointments, being personal physician to the Lord-Lieutenant of Ireland and also Inspector of Anatomy for Ireland.

The manufacture of sulphuric acid commenced in Ireland as far back as 1807 at the Dublin Vitriol Works at Ballybough. Early products, included sulphuric, nitric and hydrochloric acid, sulphate of soda, bleaching powder and Glauber salts. It is claimed that fertilisers were made in 1836, but certainly in 1854 acid was used for dissolving bones, in 1857 an artificial guano was advertised and in 1864 a mineral superphosphate. In 1868 the Dublin Vitriol Works was bought up by the Dublin & Wicklow Manure Co., and at the same time a new factory was built at Wicklow.

When the British Association met in Dublin in 1878, members visited Wicklow for the purpose of inspecting these works which produced sulphuric acid (using pyrites from the nearby mines at Avoca), salt cake, bleaching powder and chemical manures. The Wicklow factory still manufactures sulphuric acid and chemical manures, but the factory at Ballybough was closed in 1928.

John Kane was another of the early manufacturers of chemicals in Dublin, burning lime, making sulphuric acid and developing his work on salt cake and bleaching powder. Kane's was probably the first firm in the British Isles to erect and work a Gay Lussac tower, and they were responsible for the erection of a number of such towers in plants in Great Britain. Until a few years ago there was in existence a small wooden scale model of a Gay Lussac tower in the possession of the present manager of the Ulster Manure Co., at Londonderry, whose father worked in Kane's and made frequent journeys to England, believed to be in connection with the erection of these towers.

Another works which has survived to this day is that of Morgan Mooney & Co. Ltd., the founder being originally empoyed by John Kane. Probably the same products were produced in the beginning as those made by Kane, such as sulphate of soda and bleaching powder, but the manufacture of chemical manures was commenced about 1880.

In 1890, a most important event in the history of the alkali trade occurred with the formation of the United Alkali Company. This was a merger of about forty-eight companies and included all the small Irish factories which then gave up the manufacture of alkali products and produced nothing but chemical manures.

When the British Association met in Dublin in 1908, the only reference to fertilisers was in a paper by Dr. H. C. Woltereck on 'Production of ammonia from atmospheric nitrogen and peat'.

By 1908, a merger of most of the small companies dotted round the coast of

Ireland had largely taken place in order to reduce transport costs. Messrs. W. & H. M. Goulding now operate the factories at Drogheda, Wicklow and Morgan Mooney's, together with factories at Dublin, Cork, Waterford, Sligo, Londonderry and Belfast. This company is another family concern which has been in existence over one hundred years. It was in the spring of 1856 that the brothers William and Humphrey Manders Goulding commenced the manufacture of superphosphate at the Glen Works, Cork, on a factory scale, by treating crushed bones with sulphuric acid imported from England. The first acid plant was erected in 1860 using Sicilian sulphur as a raw material, but in 1864 pyrites from Avoca were employed. The factory in Dublin was commenced in 1868 and the use of mineral phosphate, steadily replaced bones. In 1872 the firm became a limited company and its prospectus referred to five hundred duly appointed agents in the United Kingdoms France, Portugal, Russia and America. It is reported that Goulding's were the first firm to ship a cargo of manures into the United States.

The large export trade to America led Goulding's in 1891 to the opening at Pensacola, Florida, of a factory with an annual production capacity of 45,000 tons. A considerable quantity of American phosphate was being shipped to Ireland, treated, and re-shipped to America as a finished product. The American factory was designed to eliminate the expensive double shipping and in addition to avoid a threatened tax on manures imported into the United States. Operations continued in Pensacola until 1905 when the works were sold to American interests.

In the early days of the fertiliser industry in Ireland the main fertiliser used apart from superphosphate was Peruvian guano. The first cargo into England came about 1840, but by 1870 it reached a peak of 280,000 tons per annum. The last cargo came into Dublin in 1923. Initially Peruvian guano was applied directly to the land, but later was treated with sulphuric acid. It dominated the market for many years, as it contained both nitrogen and phosphates and was, therefore, one of the first compound manures on the market.

Its very variable composition led to analytical control and guaranteed analyses. The first British Fertiliser and Feeding Stuffs Act came into force in 1893, but analyses were guaranteed long before this in Ireland. In 1893 Goulding's issued a pamphlet stating they had guaranteed the analysis of their fertilisers for the previous forty-five years, i.e. since 1848.

With the growth of science in the service of agriculture more and more attention is now being directed to the deficiency of trace elements in the soil. The older types of fertilisers—single superphosphate, Chilean nitrate of soda, low-percentage potash salts, etc.—contained small amounts of trace elements, whereas the more modern types—synthetic nitrogen fertilisers, triple super, ammonium phosphates and high-grade potash fertilisers—are deficient in this respect.

Single superphosphate is still the most popular form of phosphorus carrier throughout the world, although more than one hundred years have elapsed since it was first produced. It is still the cheapest form of water-soluble phosphate, and the gypsum which it contains is an excellent soil-conditioner, and also provides large quantities of calcium and sulphur, both of which are essential plant foods.

International organisations, government departments and numerous farming publications have continuously advocated the increased use of fertilisers. Soil analyses by the Department of Agriculture reveal widespread deficiencies of plant foods in Irish soils, yet it receives but a fraction of the attention required to ensure maximum fertility. Economic considerations and limited credit facilities play their part, but the fact remains that Ireland's only real natural resources, the products of agriculture, are relatively undeveloped. Despite the low rate of usage, the Irish factories producing superphosphate are unable to meet the full demand, which means a certain dependence upon imports of this product. Old factories are, however, being modernised and new ones built.

PLANT HORMONES

By Dr. P. W. Brian

There are two characteristic features of hormonal control of metabolism: (*a*) it is chemical and (*b*) the site of action may be distant from the site of production. It is now known that in the higher plants, as in the higher animals, many metabolic processes are under hormonal control. Among such hormone-controlled activities are general functions, proceeding continually throughout the life of the plant, such as cell-division and cell-extension in the growing zones of root and shoot, and more specialised functions occurring only occasionally in the life of the plant, such as initiation and development of flowers.

In some cases hormones have been isolated in pure form and their chemistry studied; in other cases the existence of a hormone has been deduced from physiological experiments and substances similar in physiological activity to the postulated hormone have been isolated from natural sources, though not actually from plant tissues. In yet other cases hormones are believed to exist but have not yet been isolated from any source. In this paper three kinds of plant hormone are discussed: the auxins, which have already made a great impact on agricultural practice, and the kinins and the gibberellins, two groups of substances which may have an important future in agriculture.

Auxins

The auxins were discovered as a result of fundamental studies on phototropism—the tendency of plants to grow towards light. The most widespread natural auxin is 3-indolylacetic acid, and it is now known that there are other auxins than indolylacetic acid, some of which are indole compounds and some appear not to be. In some growing plant organs growth appears to be regulated entirely by other auxins, but indolylacetic acid is the commonest natural auxin.

It induces extension of cells still capable of growth—the classical test for auxins—but its regulatory capabilities far transcend control of cell extension. Synthetic auxins, with molecules similar to indolylacetic acid in general shape, may have properties which enable them to be used for such diverse purposes as stimulating rooting of stem cuttings, improving fruit set, and above all as selective weedkillers.

The biggest step forward in practical use arose from the discovery that certain chlorinated phenoxy acids were not merely strong auxins but, if applied at the right dose, would kill some plant species whereas others were scarcely affected. These selective weedkillers are used in lawns and other growing crops. Production of these compounds is now a major chemical industry, crop productivity has increased and cultural programmes on farms have been considerably modified.

Hundreds of auxins have now been synthesised in further studies of herbicidal activity from which herbicides of greater selectivity, and to control weeds not previously affected, have been produced. Moreover, whilst it was once supposed that the auxin molecule must be an unsaturated ring system, substances with no such ring, e.g. S-(carboxymethyl)-dimethyldithiocarbamate, have recently been found to possess marked auxin activity, and may provide the starting-point for new syntheses with equally unexpected results as the phenoxy acid herbicides.

Kinins

Recent work on plant tissue culture has shown that other hormones beside the auxins may be involved in cell division. Cultures of some tissues will multiply indefinitely on defined media containing sucrose, mineral salts, certain vitamins and amino-acids, and an auxin. Other tissues, e.g. tobacco pith, are more exacting and require substances present in such natural sources as coconut milk or yeast

extract. Recently a pure substance named kinetin has been isolated by a group at Wisconsin University, which will to a great extent replace coconut milk or other natural additives. If kinetin is added to tobacco pith cultures at concentrations as low as 0·00001 mg. per litre, it will enable such cultures to multiply indefinitely. It has other remarkable properties: it increases leaf growth, stimulates rooting of cuttings in the presence of an auxin to an extent greater than that induced by the auxin alone, stimulates germination of some dormant seeds, but inhibits some of the cell extension effects produced by auxins.

The structure of kinetin has been determined: it is 6-furfurylaminopurine. A number of other substituted 6-aminopurines have been synthesised, some of which have kinetin-like activity, but others appear as yet to be inactive. The word *kinin* has been coined to cover all substances with this cell-division promoting activity.

Gibberellins

There is a disease of rice caused by a soil-borne fungus named *Gibberella fujikuroi*. It is in most respects a typical foot-rot, but an early and unique symptom is that infected plants grow taller than healthy ones. Over thirty years ago the Japanese had shown that a cell-free filtrate from cultures of the fungus, if sprayed on rice seedlings, would induce these extra growth characteristics. In 1939 Japanese chemists isolated a crystalline product (later found to be a mixture) which induced elongation of rice seedlings if added to culture solutions at 1 μg. per ml.

More recently in Britain and the U.S.A., a pure growth-promoting metabolite was isolated and has been called gibberellic acid. Yields in Britain have been increased to about fifty times the Japanese or U.S. yields, and there appears to be a family of related gibberellins.

The most obvious effect of gibberellic acid on plants is to increase the rate of shoot growth and of final size. In dicotyledons the main effect is an increase in length of stem internodes; in grasses and cereals increases in leaf length are the most striking effect. The dose required to produce these effects is exceedingly small: 0·01 μg. will make a dwarf-pea seedling grow visibly more in the week after treatment.

Gibberellic acid not only stimulates growth but also affects flowering and the dormancy of some seeds, tubers and resting buds. Many biennial plants produce flowers only after a spell of low temperature, otherwise they remain permanently vegetative. On treatment with gibberellic acid a number of such biennials produce flowering stalks and flowers immediately, and this substance, therefore, replaces the vernalising effect of low temperatures. On cabbage plants it is possible to produce flowering plants twelve feet high!

Conclusions

The practical advantages that have accrued from a study of the auxins are plain for all to see—the widespread use of hormone-type selective weedkillers bears witness to this. The practical uses of substances like gibberellic acid and kinetin cannot be forecast until further experimental work is completed, but perhaps the most significant future development will arise from the knowledge that in nature these hormones act in association, each modifying the responses of others. In the future it will be possible, using the natural hormones or synthetic substances modelled upon them, to modify the rate of growth, habit and flowering time of crops in the field to suit soil and weather conditions or other cultural requirements. In other words, it may eventually be possible to 'tailor' crop plants by chemical means to suit the farmer's convenience.

THE UNDERDEVELOPED COUNTRIES: SOME ASPECTS OF THEIR PROBLEMS[1]

by

A. D. KNOX

THE subject-matter of this paper is large and intricate. It should therefore begin with a warning that this is to a peculiar extent a field where every generalisation has its qualification. The underdeveloped countries cover the greater part of the world: Asia, Latin America, Africa, and parts of Europe and Oceania; and their problem of relative backwardness in economic development is also found in a number of regions which we do not normally include under the loose term underdeveloped countries.

There is some unity in their problem. They are all poor. It is a poverty reflecting their meagre heritage of capital goods and their backwardness in the techniques of production. But the differences between them are at least as significant as their similarities. In the first place, the distinction between developed and underdeveloped countries is a purely arbitrary one. There is greater difference between the income levels of the various underdeveloped countries than between those of some of the developed and some of the underdeveloped countries. Then again a great deal of the discussion of the problems of the underdeveloped countries is in terms of densely populated countries like India and the West Indies—countries that can perhaps be described as overpopulated in the sense that labour might be withdrawn from agriculture without the substitution of other factors and without materially diminishing output. But population density of this order, or anything approaching it, is not universal in the underdeveloped countries. By and large, it is not true of Africa, Latin America and the Middle East. It is not even typical of all of Asia. Burma, for example, is a relatively thinly populated country. We also tend to associate backwardness in economic development with economies where external trade is the dominant feature of economic life. It is perfectly true that in many underdeveloped countries exports account for anything from 20 to 40 per cent of gross national product. But it is well to remember that in India, for example, 5 per cent is much closer to the mark; and much the same goes for China.

Lastly, we should keep in mind that the whole history of economic expansion differs considerably between the underdeveloped countries. Two hundred years ago British governments were more interested in the potential wealth of the West Indies than in what were then regarded as the wastes of Canada. By contrast it is less than a hundred years since parts of tropical Africa began to develop any significant commercial contact with the rest of the world. Prior to that, exports from East Africa were largely limited to ivory, which could bear the high costs of transport, and to slaves who provided their own. Neither were commodities with significant positive multiplier effects. Indeed, there is a contrast between countries that have long been struggling to avoid stagnation and those that have only recently emerged from a long sleep and are progressing with some rapidity. There is a further contrast, within countries, between regions of rapid growth and those of stagnation. No overall statistics reveal the uneven growth within the underdeveloped lands. This is, of course, a universal problem; but it appears to take a particularly acute form in the world's poorer countries. It is in many ways the crux of their problem. Growth has been insufficiently pervasive.

[1] Address delivered to Section F (Economics) on September 9, 1957, at the Dublin Meeting of the British Association.

But what lies behind this backwardness and this uneveness in economic growth? To pose the question is to open the floodgates of speculation. Some argue that the resources of the underdeveloped countries are unfavourable to ready growth; others that in the present state of our knowledge we know more about ways of expanding production on the soils of the temperate lands than on those of the tropics; and others again claim that, while tropical and sub-tropical climates may have been more conducive to the flourishing of civilisation while man's techniques were still simple, they have proved more difficult to master than have the temperate climates. These are all, in some measure, debatable issues. But, even if they were all to be accepted without question, we should not be at the end of the matter. 'It is incumbent on the economist', as Professor Viner has put it, 'to recognise and to proclaim that economic improvement is not merely a matter of more capital, or more acres, or more coal in the ground, but also of growth of effectiveness of management and of manual effort through better education, better health, better motivation, and better political and social organisation. If he fails to do so, he is liable to find himself throwing the blame for national poverty wholly on physical resources beyond human remedy, or on factors external to that economy, to the neglect of the internal human, social, political and moral factors which may carry a large part of the true responsibility.' (1)

The warning has been heeded. The writings of economists on economic development are full of references to the 'human, social, political and moral factors' of growth: the problems of the incentives to work, the effects of family systems and of the organisation of land tenure, the hindrance to development of an illiterate population, the difficulties of technical training in languages lacking the appropriate words, the consequences of corruption and inefficiency in government. . . . This is the merest sample of the forces recognised as having some part in economic growth. It could be multiplied many-fold.

The variety of hypotheses springs from the nature of the problem. Economic development is a revolutionary change involving readjustment in far more than just the level of output in a country. Clearly no simple explanation for such a change can be found. Clearly also many forces other than those that lend themselves to economic analysis are at work. But there is always some danger that in seeking to give due place to the importance of non-economic forces, economists may fail to recognise how many of the characteristics of the underdeveloped countries have an explanation in the lack of economic opportunity in those countries; and that they may ascribe to them a degree of resistance to change that is pessimistically great. There is a strong school of thought that the motives governing action in the underdeveloped countries are materially different from those in the richer parts of the world. Gunnar Myrdal has put this view in his *Economic Theory and the Underdeveloped Regions*: 'Even if there are profits to be made in industry, there are no entrepreneurs to seize the opportunity; or those, which there are, have not the skill to do it so that the profit would be realised. Even more fundamentally, the search for profit is not as universal a motive for human behaviour as the classics supposed: in underdeveloped countries the appreciation is, in particular, slight for that type of profit which accrues from sustained production efforts and long-term capital investment' (2). There is an element of truth in his contention. The underdeveloped countries are often lacking in knowledge not merely of the techniques of production but also of the arts of management. There is a further element of truth. If we examine a stagnant society at a particular moment of time, as we are sometimes prone to do, we not unnaturally find evidence of characteristics inconsistent with dynamic change. But therein lies our problem. So much of our information relates to what prevails at a particular point of time. Because we are describing what appear to be the current obstacles to change, we are in constant danger of overstressing them and of endowing them with a permanency they do not possess.

The institutions and customs of a stagnant society are adjusted to stagnation. That does not prove that, if market opportunities and incentives for expanded output appear, they will be permanently ignored.

It is a chastening experience to review what has been written in the past about the African's lack of material wants. Fifty years ago, and even less, in East Africa the evidence was heavily against any response by Africans to the new possibilities opened up by the development of transport and the introduction of new crops. But imitation has done its work (3). Wants have grown, and with them has come a changed response to the possibilities of the market. Indeed a great deal more seems to depend on the extent of the market than simply the opportunity for investment. The actual responsiveness of peoples to market conditions is not unrelated to the market's size.

No one expects social and institutional and other obstacles to change to disappear overnight; but some, at least, can be more flexible than we are sometimes prepared to believe. Thus African systems of land tenure are a favourite illustration of non-economic obstacles to growth. The argument is that the communal emphasis so often found in these systems restricts initiative in a way not found in more individual forms of tenure. It is possible that a case may be made out for this point of view; but it is interesting to notice that in West Africa the traditional forms of tenure have persisted most tenaciously in the production of food which is largely on a subsistence basis and with very restricted market possibilities. They have changed most drastically where land is used to grow crops for sale; and nowhere have they changed more than with cocoa land, where specialisation in the production of a cash crop has probably gone farthest. It is possible to argue that this 'may mean that food is grown on land where old customs rule, where new methods are held back by the interference of tribal and family elders, and where the "economic man" cannot feel any personal advantage in improving the land: while cocoa is grown on land where the enterprising individual is free to plan and work and earn the return of his skill' (4). But it is also possible to argue that the traditional tenure system is economically well suited to subsistence production where the market is non-existent or at best limited. In a society where people obtain the goods they need almost wholly from their immediate environment and by their own direct effort, no commodity is more valuable than land and in no circumstance is it worth while to dispose of land. Land in such a society has no exchange value (5). Individual tenure and exhange have no place. There are cases where the resulting customary tenure is inimical to any commercially profitable use of land. Dr. Mair, in her *Studies in Applied Anthropology*, cites the example of Basutoland, where arable lands are thrown open after harvest for common grazing and where in consequence no one can plant a permanent crop. But she goes on to observe that

> the history of change in African land systems is precisely the history of the manipulation of the traditional rules in order to profit by new opportunities, and, sooner or later, the rejection of those that are found to be irksome. It can rarely be demonstrated that any customary restriction on individual enterprise has prevented the introduction of a new form of land use which offered a good hope of profit. . . . It is a matter for investigation how far the assertion often ascribed to African farmers, that they are afraid to have good fields because the 'chief will be jealous' or 'their neighbours will be jealous', is a genuine reason; and how far it is an excuse. . . . It is significant that this kind of explanation of reluctance to improve methods of cultivation is most often heard in the regions where it has been hard to find a profitable crop. It is the answer to propaganda for soil conservation methods, or for measures to improve the yield of the traditional food crops, from which the African farmer rarely expects to get benefits commensurate with the extra work involved (6).

Economists at times seem strangely reluctant to follow the anthropologist in being

as economic in analysis as this. But this is a useful reminder that when economists look to anthropologists to provide the explanation of phenomena that at first sight seem to lie wholly beyond the confines of economics, they may find anthropologists looking to them.

It would be idle to argue that social forces cannot slow down the rate of change in an economy, or that economic growth does not bring with it social strains. That certainly is not Dr. Mair's argument. The point is rather the changes that can occur when a market opportunity offers. It may perhaps be permissible to cite another illustration from Africa which is to be found in E. H. Winter's study of the *Bwamba Economy* (7). The Amba live in a relatively isolated area of Western Uganda. Before 1920 their contact with the outside world was limited. They exported some food in exchange for salt and the iron used in making their weapons and tools. But in the 1920's there began various efforts to introduce coffee and later cotton. The pattern of development is a not uncommon one: initial resistance followed by a steady expansion of the acreage under cultivation. This early development took place despite the absence of easy transport to markets. It was not until 1938 that the completion of a road 'meant that the cash crops which had formerly been exported with great effort by head-load could now be removed by lorry' (8). The economic change that has occurred despite these highly unfavourable conditions has been considerable. 'First, there was the introduction of new crops, particularly the cash crops, coffee and cotton. Second, it should be noted that in the case of coffee this meant a considerable amount of saving and investment. Labour had to be expended on the development of the coffee trees for four years before any returns were realised. Once this period was completed the grower was left with a permanent asset. Third, a considerable expansion of agriculture was undoubtedly involved' (9) and it may be estimated that the acreage under cultivation rose by 50 per cent. This hardly suggests a slight appreciation 'for that type of profit which accrues from sustained production efforts and long-term capital investment'. On the other hand, it would be a distortion to argue that the Bwamba economy is in the curious position of being driven solely by a naked desire for material gain. Winter observes that the division by which the womenfolk have control over the food crops while the men enjoy the proceeds of the cash crops is some deterrent to cash crop production in a society where women do most of the work in the field. The suggestion that extra effort would be forthcoming for cash crop production if the women received some of the fruits of this effort has apparently not been well received. The fear of the Amba men is that 'once a woman had saved enough money she will then be able at any time to give her husband the amount he had paid for her in bridewealth and leave his home. The men say that the women are difficult enough to control as it is, and if they once had funds at their disposal there would be no way of exercising authority over them' (10). Thus can social organisation thwart the working of economic forces; but only, it seems, by divorcing effort and reward.

These are very few illustrations in a vast and complex field of social organisation. But they serve my purpose, which is simply to argue the dangers of a static approach to a dynamic problem; and in particular the danger of assuming that, because economic motives do not seem to apply where economic stimulus is lacking, they never apply. I do not wish to suggest that there is no problem. The success of immigrant peoples in underdeveloped countries—and indeed throughout history—is only one strand of clear evidence that local peoples do not always grasp the opportunities that come their way. I do not seek to belittle the very real social and institutional obstacles that exist. But we must beware of exaggerating the problems of underdeveloped countries and of suggesting that economic man, even in the emasculated form in which we know him, lives only in our part of the world.

This does not suggest that the problems of promoting the economic expansion

of underdeveloped countries are in any sense easy. Revolutions are not easily produced. They require a powerful impulse. Economists have for long sought the impulse for economic development in the growth of the market and the opportunities it offers; and the idea that markets depend on production and production depends on markets is familiar. 'All demand is mutual demand and expansion by one industry is a demand for and is dependent upon expansion by another. Solitary expansion, either by one industry or by one country, is not impossible, but it is difficult. Economies to be truly effective must be made on a broad and not on a narrow front' (11). Because the growth of different parts of the economy is thus interdependent, difficulties of expansion in any major part can retard the growth of the whole. If we were dealing with closed economies the difficulties of industrial development experienced in underdeveloped countries would go far to explain the slowness of their growth and indeed the stagnation of their agriculture.

But we are for the most part not dealing with closed economies, although for a country such as India the assumption would not be all that wide of the mark. In an open economy there is clearly greater scope for differential rates of expansion. This is precisely what has happened in underdeveloped countries. Their problem, however, is not that growth has occurred at different rates in different sectors, but that it has been so uneven in its incidence. An input–output table which depicted the export sector of an underdeveloped country as having little connection with other parts of the local economy would quite often paint a very accurate picture. Internal trade is certainly not non-existent. Some exchange, generally in barter terms, can exist within the subsistence sector; and Bauer in his *West African Trade* has drawn our attention to the considerable enterprise of Africans in developing exchange within West Africa of purely indigenous products like kola nuts and dried fish (12). But internal trade in other areas still appears to be extremely small in comparison to external. Thus in 1954 'Kenya's total domestic exports within East Africa amounted to £5·8 million, as against total domestic exports abroad of £20·3 million, a ratio of 1 to 3·5; the comparable figures for Uganda are £7·5 million and £40·6 million, and for Tanganyika £1·0 million and £36·3 million, ratios of 1 to 5·4 and 1 to 36 respectively' (13).

In other words, the impact of what are often flourishing and rapidly expanding export sectors on the rest of the economy is often small. Quite a variety of reasons can be found for this. The problem of 'dual economies' found in some Eastern countries arises from the development of export sectors by both external capital and external labour. The tea industry of Ceylon is a case in point. For long it was the almost exclusive preserve of British capital and Indian labour, reflecting both some resistance to change by the Ceylonese and, more important, ample alternative opportunities of livelihood. In other places the low multiplier effect of the export economy is associated with the exploitation of base metals. That these should have a low multiplier effect in the mining area is not peculiar to underdeveloped countries. Studies of industrial location in the United States show that a common feature is the 'refining of ores at the source usually by simple processes that do not employ much labour or add greatly to local income. . . .' (14).

These illustrations help to show that the repercussions of exports in an economy can be very small. But my purpose is not any attempt at a comprehensive review of multiplier effects. I want to discuss two ways in which the absence of market opportunities manifest themselves in underdeveloped countries. Sometimes we find both together; and at others, only one. The first is the importance of subsistence production; and the second the difficulties of industrial development.

The market problem of the underdeveloped countries is not solely the poverty of the internal market. We have to add the division of the poor aggregate market into a series of sections. This reveals itself in lack of transport and trading facilities and the resulting differences in prices between adjacent regions and in problems of

regional famine such as do not occur in more integrated economies. Most important, however, is the fact that a substantial portion of the economies of most underdeveloped countries is on a subsistence basis. Thus one estimate is that subsistence production occupies between 65 per cent and 75 per cent of the total area of tropical Africa under indigenous cultivation. For particular countries the proportion in the subsistence sector varies from 93 per cent in Kenya to 25 per cent in Ghana. Similarly, it is estimated that of the total male population in tropical Africa over fifteen years of age, 40 per cent are engaged in money-earning activities and 60 per cent in subsistence production (15). We find something of the same pattern in Central and South America. In Mexico, 'about 70 per cent of the population has lived wholly or largely outside the commercial framework, although Mexico actually has had a more diversified economy than most of the Latin-American countries' (16). The pattern in many other underdeveloped countries is similar.

The subsistence sector of the economy is the poorest and the most backward in production techniques. We have already contrasted the change in land tenure arrangements on land used for cash crops with those where the land is employed for subsistence food production. The reasons for the backwardness of the subsistence sector are many. It can be argued that less attention has been devoted in many countries to propagating improved methods of food production than to popularising better techniques for export crops. It may be argued that in a society uncomfortably close to the danger of famine people will cling with particular tenacity to known food production methods, lest experiment spell disaster. That is all true; but it must also be remembered that this is to a peculiar degree a part of the economy where the improvement of production techniques would create a problem of what to do with the marketable surplus which would emerge. There are no readily available markets for the output of the subsistence sector. The development of the export sectors has left the subsistence sector behind partly perhaps because of difficulties of transport, which is an almost universal bottleneck in underdeveloped countries, and partly also because specialisation has often not gone far enough in the export sector to create a sustained market for foodstuffs. In Ghana, for example, 'primary income is derived almost entirely from highly specialised cocoa cultivation, giving rise to a large concentration of population dependent on food purchased from other producers. In Uganda, on the other hand, primary income is derived mainly from cotton grown by peasant cultivators in rotation with subsistence food crops. Here the essential subsistence nature of the economy is maintained; there is little market demand for food and the demand for non-food products is satisfied mainly through imports. Consequently the cumulative effect of primary income is small' (17). The Uganda example rather than the Ghana one is typical, 'since the greater part of the indigenous export crop is produced under conditions of modified subsistence farming' (18). The developing sectors have not, by and large, developed far enough to draw the subsistence sectors into the 'modern' economy.

Because the subsistence sector languishes in stagnation, it is in turn a drag on the rest of the economy. It provides little or nothing in the way of markets. It can be argued that it provides a pool of low-wage labour, because of its poverty of alternative opportunities, and that the availability of such a supply favours development. But, as in Africa, it may be a migratory supply with a high turnover and thus a particularly low efficiency. And, moreover, low-wage labour is a poor incentive to development where a subsistence sector constricts the market. Clearly one of the most critical tasks of economic development is to bring this sector into the exchange economy for on its expansion so much else depends.

A second significant way in which the development of exchange is hampered in underdeveloped countries is in the absence of manufacturing industry. 'The great commerce of every civilised society', wrote Adam Smith, 'is that carried on

between the inhabitants of the town and those of the country. It consists in the exchange of rude for manufactured produce, either immediately or by the intervention of money, or of some sort of paper which represents money. The country supplies the town with the means of subsistence, and the materials of manufacture. The town repays this supply by sending back a part of the manufactured produce to the inhabitants of the country' (19). I am not suggesting that industrialisation is the answer to the problems of underdeveloped countries. Indeed, in those where population density is low, it is possible that an expansion of export crops and an extension of the exchange economy into the subsistence sector would serve them better (20). But certainly a case for it can be made in those countries where population is pressing hard on the land. Here the lack of market takes the form of an absence of employment opportunities alternative to agriculture. It is a lack of market which confronts the densely populated underdeveloped countries with a continual problem of seeking labour-intensive methods in a world where the research resources of the richest countries are devoted to saving labour. This need to absorb more and more labour is in many cases a drag on the efficiency of their agriculture. It is a dilemma whence, for the most part, they can escape only by the development of secondary industry.

As with everything else in economic growth, there is a multitude of factors influencing prospects of industrial development in some way or other. I may perhaps be forgiven for concentrating on a few. The growth of secondary industry aimed at the home market is difficult because that market is poor and small. Growth aimed at external markets is difficult for many underdeveloped countries because they lack developed resources of power and accessible raw materials for the manufacture of metal. For some it seems to be a case of complete absence, at any rate so far as investigations of their resources have so far shown, of one or other of these ingredients of industrial expansion. For others potential resources exist but, to be made effective, they require 'lumpy' investments beyond their current means and yielding a return only in the long term because they would be so much in excess of current requirements. These are the problems of hydro-electric development or of the development of transport to allow the exploitation of mineral resources.

Now the lack of power and of mineral raw materials does not preclude development. Some industries use little of either. Nor does it even preclude the development of industries using substantial quantities of one or both. Fuel and raw materials can be imported (21). But to remain competitive in the face of transport costs requires that other factors get less than they command in more favoured countries. Very largely this means an industrial development on the basis of low-wage labour. Professor Lewis has argued that the dilemma of the underdeveloped countries is that in their efforts to keep up their standards of living, they curtail their prospects of development (22). The requirement of industrial growth is thus to accept lower real wages. But even if we accept that it is possible to encourage industrial development on the basis of low real returns to domestic factors of production we still face the problem that such a development creates a domestic market limited in relation to other countries. Once again the multiplier effect of an expanding sector is limited. The stimulus imparted by industrial development to other parts of the economy is hampered.

Fortunately this is not true of all. It can be argued that it paints somewhat too gloomy a picture of India's industrial resources. The emergence of hydro-electric power in Uganda has begun to change the situation there. But it is very much the problem of many underdeveloped countries.

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ECONOMIC GEOLOGY OF IRELAND[1]

by

MURROGH V. OBRIEN

THIS PAPER, when presented to the Association, was fortunate in following directly after those of Professors Brindley and Gill. With the background of the geological map of Ireland already explained by them, the author was able to turn rapidly to the economic aspects of Irish geology.

The lecture dealt primarily with the geology of the metalliferous deposits. Sedimentary mineral deposits—coal, gypsum and limestone—were also referred to, as were some of the problems of soils, water supply and engineering foundations. Although all of those are matters of substantial economic importance, they were dealt with briefly because they conform more closely to conditions with which members of the Association are likely to be familiar.

Metalliferous deposits had, after a productive half-century, been rather neglected from 1880 till after 1940. Since then the renewal of prospecting and mining activity (some aspects of which were described by Prof. M. A. Hogan to Section G) gave opportunities for renewed geological examination. And in their turn, geological studies have, in conjunction with a Government lead in mineral exploration and with economic and taxation changes, helped in the mining resurgence.

Through the latter half of the last century Ireland was almost completely mapped on the 6″ to 1 mile scale by the Geological Survey. But even before, and independently of that, a large number of occurrences of metalliferous minerals were known. The recorded list now is long and, even omitting those which are apparently trivial or where there is little geological information due to poverty of exposure, it would be easy to degenerate into an annotated catalogue. Copper, lead and zinc are the metals which appear repeatedly, dominantly occurring as their common sulphides. Iron pyrites and silver are sometimes important accessories, and have also been worked on their own. Gold has two interesting occurrences which will be noted. Cobalt and nickel are known but have yet to be proved to be present in economic quantities. And in that category also are some very interesting molybdenite deposits. Iron is known only from bodies of small size or low grade, or in the form of pyrites.

From these only a few can be selected for more specific mention. The information is drawn both from the author's own experience and from published information.

The largest known body of sulphides in the country is at Avoca, County Wicklow. There the Ordovician rocks, a varied series of muddy sediments and mainly acid tuffs, lavas and minor intrusives have a strong Caledonian trend, dipping about 55° to the SE. These are about 10 miles from the SE. flank of the Leinster granite (early Devonian) and have been strongly affected by movement prior to and during the intrusion of that mass. The mineral texture and composition of the rock has suffered not only from the regional deformation and weak metamorphism but also from the widespread alteration associated with the introduction of the sulphides. This manifests itself variously in the development of chlorite, sericite, quartz and pyrite. Through these rocks runs a shear zone, also dipping 55° SE. Along 2½ miles it contains a series of lenticular ore bodies, some reaching 2,000 feet in length and over 100 feet in width. In these pyrite, zinc blende, galena and chalcopyrite have in turn replaced the earlier minerals more or less completely. The resulting sulphide ore can have from 10 per cent to 80 per cent of sulphides,

[1] Address delivered to Section C (Geology) on September 5, 1957, at the Dublin Meeting of the British Association. Mr. M. V. OBrien is Director of the Geological Survey of Ireland.

but even in the latter case it characteristically retains the banded structure inherited from the schistose rocks of the shear zone.

The early pyrite was intensely crushed before the introduction of later sulphides and the ore bodies are broken by N–S faults with shifts of several hundred feet. Late felspar porphyry was intruded in places along the hanging wall and the post-mineral faults, and across the ore. Therefore mineralisation spanned a period of movement and preceded the last igneous activity. It is at present a reasonable conjecture to link these events with the time of the granite emplacement.

In far later geological times the zone was cut midway by the 700 feet deep Avoca valley. The nineteenth-century workings were on primary sulphides, and not to any important extent on ores due to oxidation or secondary enrichment, yet they bottomed on a plane paralleling the modern topographic surface. It would have been a very odd coincidence if Caledonian mineralisation had adopted a lower limit which was paralleled by quaternary erosion. The conclusion that nineteenth-century production was in fact strictly limited in depth by the working head of the pumps, and not by exhaustion of the ore, was an important argument for the resumption of deep exploration. The ores since found, in excess of 20 million tons, are valuable principally for their $1\frac{1}{4}$ per cent copper, but they contain considerable pyrite also, and lead and zinc in part.

While Avoca was the leading nineteenth-century copper producer, Glendalough, only 12 miles away, was by far the country's most productive lead mine. But it is strikingly different in its geology. Veins, up to two miles long, run through the uniform Leinster granite as near ruler-straight as nature could make them. Fracturing can only have occurred when the granite was quite rigid. The vein contents of coarse galena and zinc blende, with quartz and rare chalcopyrite, has a 'comb structure' and other features which make fissure filling an adequate explanation of their emplacement. The walls of the fissure faults moved laterally, relative to one another, so that a slight deviation in one sense from the mean direction tightens the vein, while a slight deviation in the opposite sense has the effect of opening it, in which case it can have a filling of sulphides, quartz and crushed granite exceeding 4 feet in width. The wall-rock granite is softened by breakdown of the felspars only for a foot or two each side of the main veins.

At Glendalough the veins die out shortly before reaching the mica schist aureole, which represents Lower Paleozoic strata at the contact. Otherwise similar occurrences, as at Glenmalure a few miles further south, show the veins continuing mineralised for some distance into the schist. Neither of these nor any of the smaller vein systems of 'Glendalough' type extend to the overlapping Devonian or Carboniferous sediments, so a later limit for their age cannot definitely be set. But since the Leinster granite began to be unroofed before the end of Devonian time and has not lost much more from its highest levels since, it is easiest to visualise the veins now outcropping as pre-Carboniferous.

South-westwards the Leinster granite plunges under Lower Palaeozoic strata, but the onward projection of its axis meets the coast at Bunmahon, Co. Waterford, where copper deposits have been extensively mined. It is tempting but unwarranted (though not necessarily wrong) to attribute both Avoca and Bunmahon, and perhaps the half-way lead-copper occurrence at Caim, Co. Wexford, to mineralisation from buried offshoots from the Leinster granite. At Bunmahon the age of the deposit could be consistent with such a story. Veins cutting Ordovician rocks are earlier than the local lowest Devonian beds, whose basal conglomerates are clearly seen on the cliff as unconformable across the top of the 'Stage Lode'. The vein pattern is utterly different from that at Glendalough, because here the fractures, cutting across the regional strike, met such very varied rocks—mudstones and shales with volcanics and occasional limestones, all with innumerable irregularly ramifying dykes. Thus a fracture could rapidly change from a clay-lined plane to a

straightforward quartz vein, carrying copper pyrites, or to a shatter zone, 60 feet or more in width, filled with the same minerals. Replacement seems to have played only a subsidiary part because most of the included fragments in the breccia veins are sharp edged and barren. The Bunmahon lodes (one is over 1¼ miles long) show no evidence of post-mineral intrusion, as at Avoca. But their geometry is complicated by heavy barren post-mineral faulting belonging to the Hercynian earth movements, which were violent enough in that area to set some of the Devonian beds on end.

One hundred miles away, through West Cork, the same Hercynian fracturing initiated a period in which quartz and chalcopyrite were deposited in the compact but unmetamorphosed Devonian sandstones. So many of the minor occurrences of this type lie in the topmost Devonian beds (sandstones and sandy slates) that it has from time to time been postulated that these sediments included copper as an original constituent. Thin stains of malachite are certainly conspicuous along the beds, but all the copper sulphides (chalcopyrite and occasionally tetrahedrite or bornite) are in quartz veins, or veinlets, or within an inch or two of them. It might be argued that the quartz and copper were both segregated together from a cupriferous sandstone. But that argument becomes difficult to sustain at Ballycummisk where barytes and micaceous hematite are intergrown with the chalcopyrite and quartz. And it becomes untenable at Allihies. The Allihies deposit is typical of the West Cork copper-quartz vein in all but the size of its veins, which have been mined to produce metal almost equivalent in amount with Avoca and Bunmahon. The old mine plans and exposures are supplemented by almost bare hillsides and sea cliffs. Strongly copper bearing veins up to 50 feet thick traverse a wide range of Devonian beds, the 'Mountain Lode' alone cutting 1,800 feet of strata, all well below the top of the system. Not only does it look like an introduced ore, but the time of fracturing can be fixed as the time of the end of the main Hercynian folding there. The symmetry of the fracture pattern coincides with the axes of the plunging major and minor folds. The veins are unusual in having right-angle double bends, not due to subsequent folding or faulting. It is at these sharp inflections, almost Z-shaped in plan, that the greatest widths and copper contents have been found.

In the Carboniferous limestone lead-zinc deposits, sometimes with copper, are numerous. Their structural setting varies. Examples are to be found in the tight folded and overthrust syncline of the Kenmare valley, Co. Kerry, along a major normal fault running E–W at Silvermines, Co. Tipperary, and in quite gently tilted and deformed beds between two big faults at Ballysodare, Co. Sligo. In the case of Silvermines galena mineralisation extends along fractures into the Devonian sandstone on the upthrow side of the fault, in addition to there being mixed sulphides along the brecciated fault zone and irregular replacement bodies of galena and blende spreading into the dolomitic limestone beds. The zinc rich portions are deeply oxidised to give mixed zinc carbonates and silicates, in marked contrast to the scarcity or absence of oxidation on most other Irish sulphide bodies.

The Ballysodare deposit, which has produced more zinc than any other in the country, has an important ore control in the form of a 24-foot-thick calcareous grit between the thin bedded limestones. Blende and galena tend to occur most consistently in the upper part of this grit bed, and in the few feet of limestone immediately over it. It seems as if the different behaviour of the two rock types in the gentle folding developed small cracks from which both replacement and cavity filling could extend.

Almost as far removed from evidence of igneous activity is the antimony-bearing vein cutting Silurian sandstones in Co. Monaghan, which has recently been reported as carrying gold with the arsenical pyrites disseminated in the wall rock. Before that gold was known from alluvial gravels in certain Co. Wicklow streams and as an insignificant constituent of some base metal ores.

By contrast the molybdenite in the margin of the Murvey, Co. Galway, granite can, from its distribution, only be reasonably explained by supposing it to have been a constituent of the magma as it cooled. Smaller dispersions of molybdenite elsewhere in Galway and Donegal are all closely associated with granites, though they may be in aplites, pegmatites, quartz veins, skarns or sulphide patches.

The relative frequency of metalliferous mineral deposits reflects the fact that most of Ireland is underlain by rocks of considerable age and diversity, which have suffered repeated deformations, and perhaps also because of their varied content of igneous rocks. It is with just such a background that we can expect some, at least of the rather complicated kinds of coincidence which are necessary for the formation of accessible concentrations of useful minerals. The essentials of these coincidences are that at one and the same time there should be:

(i) minerals rendered mobile, as by heat, pressure or solvents;
(ii) channel-ways opened through which they can move without undue dispersion;
(iii) conditions developed where within compact limits minerals lose mobility and become fixed, whether by loss of heat or pressure, or by chemical precipitation or by physical prevention of escape.

It must be constantly borne in mind that every mineral deposit should be judged on its own individual characteristics. That does not mean that comparison between ore bodies should be disregarded, but that argument by analogy from one to another must be regarded with extreme caution. And the utmost caution is called for when dealing with the wider generalisations of the type that try to link each mineral deposit to a particular kind of intrusive or that try to force them into a few set periods of emplacement.

The Irish deposits, even in the limited selection dealt with here, are quite sufficiently varied in style, setting and date to illustrate a range of individuality. That conclusion seems valid even though we are still far from a full knowledge of them. They offer scope for much more study which may be both scientifically and economically beneficial.

PARTICLES IN PLANT AND ANIMAL CELLS[1]

by
Miss R. J. A. KIRKLAND

Introduction

Since the advent of the light miscroscope in the sixteenth century attention has been drawn to the structure of plant and animal tissues. The nineteenth century witnessed a marked interest in the application of the light microscope and it was rapidly established that all organisms consisted of cells and that within these cells a complex structural organisation existed. In recent years with further developments in histochemical techniques and with the invention of the electron microscope there has been a tremendous increase in our knowledge of cellular structure.

It is now apparent that cellular architecture is far more complex than first imagined. The gross structure of tissues has been well documented but it is only in the last two decades that an intense study of the structural, chemical and biochemical properties of cellular particles has been possible. The literature on studies of particles from animal cells is now very extensive, while information about similar plant structures is rapidly accumulating. The intense structural organisation of cells suggested an associated functional significance and it has been possible to demonstrate that this is indeed the case.

The ground substance of the cell, the protoplasm, is enclosed within a membrane, and a more rigid cell wall in the case of plants. The protoplasm is differentiated into particles of varying dimensions, composition and biochemical activities. The nucleus, the largest single intracellular particle, is the seat of genetic inheritance, while the mitochondria and microsomes appear to be the site of an infinite variety of biochemical activities of utmost importance to the metabolism of the cell. Other particles, the centriole, Golgi apparatus, the structures of the endoplasmic reticulum, have been described and possible functions assigned to them. Other cellular inclusions in special cells are recognised by cytologists, for example lipid and glycogen granules in liver cells. Large elements, the chloroplasts, present in certain plant cells are the site of photosynthesis a vital process whereby light energy is converted into utilisable chemical energy. Mature plant cells are also characterised by the presence of vacuoles which may contain considerable amounts of organic acids in addition to pigments, inorganic ions and sugars.

Certain aspects of the characterisation, structure, chemical and biochemical composition of these particles will now be considered.

Methodology: Cytology and Isolation

In 1831 Brown described the widespread occurrence of nuclei in cells. Nuclei can be observed in living cells with the aid of the light microscope and are characterised by a positive Feulgen reaction. Mitochondria were probably first observed and described by Altman in 1890. However, two decades passed before Bensley paved the way for future intensive study by reintroducing Janus green B as a vital stain of mitochondria. These particles have been stained in living tissues, but, as in the case of other cellular particles, most studies have employed material which has been fixed and stained. Phase contrast, fluorescent, ultra-violet and electron microscopy have proved valuable in revealing the structure of cellular particles.

The method of differential centrifugation of tissue homogenates, introduced by Bensley and Hoerr in 1934, heralded a new era in research on cellular particles.

[1] Essay awarded first prize in the 1957 Endeavour Essay Competition. Miss Kirkland is a student at the University of Sydney, New South Wales.

This technique relies on the differential rate of sedimentation of particles of different density. In this way it is possible to fractionate a tissue into a soluble fraction, nuclear, mitochondrial and microsomal fractions. Since cellular structures are extremely sensitive to altered environmental conditions and artifacts may arise by disruption or adsorption, careful attention must be paid to the pH, tonicity and temperature of the suspending medium.

The most suitable methods for the isolation of nuclei appear to be those in which the suspending medium is sucrose supplemented with calcium chloride or citric acid.

In the isolation of mitochondria and microsomes 0·88 M, 0·44 M and 0·25 M sucrose have been successfully used. A number of substances, including proteins, chelating agents and cysteine, have been utilised to activate or stabilise the mitochondria during and after extraction.

The Golgi apparatus has been observed in animal tissues after special fixation and osmication. The structure has also been isolated by a density and gradient method.

Morphology

On viewing a cell perhaps the most prominent intracellular structure is the spherical or oval nucleus which represents about 10 per cent of the total mass of the cell. The diameter of the nucleus in a liver cell is 8 to 10 μ. Most cells contain only one nucleus but some, for example muscle cells, possess numerous nuclei per cell. The nucleus is surrounded by a double layered membrane containing pores, but no membranes appear to delimit intra-nuclear structures (Moses, 1956). The space between the two nuclear membranes appears to be in continuity with the cavities of the endoplasmic reticulum.

One or two rounded bodies, the nucleoli, containing ribonucleoprotein particles are frequently present within the nucleus. Localised in the chromosomes within the nucleus are the genes—the vital units of inheritance. The chromosomes of animals and plants are composed of closely appressed, helically disposed chromonemata (Gay, Kaufmann and De, 1956). Chemically, deoxyribose nucleic acid (DNA) is the most important constituent; histone and non-histone proteins are also present.

A tiny granule, the centriole, is often observed in animal cells which are capable of dividing and is frequently surrounded by a spherical zone of specialised cytoplasm, the centrosome.

The application of electron microscopy has been of tremendous importance in elucidating the fine structures of cells.

Animal mitochondria may vary in length from 1 μ to 4 μ and in diameter from 0·3 to 0·5 μ, depending on the cell and the conditions to which it has been subjected: 1 μ is a typical value for the diameter of a granular plant mitochondrion.

The characteristic internal organisation of plant and animal mitochondria suggested by electron micrographs was described by Palade (1952, 1953). The intramitochondrial structures include a limiting membrane, a mitochondrial matrix and a system of internal ridges, the *crostae mitochondriales*, protruding from the inside surface of the membrane towards the interior for varying distances. Sjöstrand (1953) has shown that the outer and inner membranes of an animal mitochondria are double, consisting of two protein layers separated by a lipoid film. The cristae appear to be folds of the second internal membrane and it is believed that enzymes are situated on, or may form part of, their structure. A similar pattern of organisation seems to prevail in a wide variety of vertebrate and invertebrate tissues as well as lower and higher plants.

A variety of physical and chemical agents can cause profound morphological alterations in mitochondria resulting in granulation, vesiculation or the coalescence to form filaments. Some of these changes are reversible and it appears that the

mitochondria of the fungi, *Allomyces* and *Achlya*, are less sensitive to external agents than those of higher plants.

Striated and cardiac muscles of vertebrates consist of fibrils with granules between them. These granules, termed sarcosomes, have been identified with mitochondria.

The endoplasmic reticulum observed in animal and plant cells is a finely divided vacuolar system wtih membrane bound vesicles permeating the entire cytoplasm from the cell nucleus to the cell membrane with which it appears to be in continuity, at least intermittently.

Some cell types show a limited degree of organisation in the reticulum, others are highly organised, while some show an intermediate degree of organisation. Smooth and rough surfaced profiles have been described. Randomly disposed, smooth surfaced profiles seem to predominate where there is less organisation of the reticulum. The term *cisternae* has been proposed for the flattened vesicles present in many cells and intracisternal granules have been described in the exocrine cell of a guinea-pig pancreas (Palade, 1956). It has been suggested that the endoplasmic reticulum participates in secretory processes and is involved in the import, export and intracellular circulation of various substances. The relationship of microsomes to the endoplasmic reticulum will be considered later.

According to several workers the Golgi apparatus in vertebrate somatic cells is a vacuolar structure with chromophilic walls and a chromophobic lumen. This lumen is vacuolar with granules. There are two main types of vesicular structures in the rat spermatid—flat vesicles generally accumulated in stacks and spheroidal vesicles. It is suggested that the Golgi apparatus is concerned with the concentration and segregation of lipid absorbed by duodenal cells and in the segregation or removal of water from secretory granules in other cell types. The Golgi complex is involved in the formation of the acrosome during spermatogenesis.

Chloroplasts are characteristic of the green, chlorophyll containing, cells of plants. The chloroplasts of lower plants and the chromoplasts of brown algae exhibit lamellae but grana appear to be absent. Grana are present, however, in higher plants. Chloroplasts consist of a system of densely staining lamellae (*ca.* 125 Å thick) embedded in a finely granular matrix, the stroma, and are bounded by a limiting membrane which often appears double, especially in young plastids.

In the parenchyma sheath chloroplasts of *Zea mays* (Hodge *et al.*, 1955) grana are absent and the lamellae extend the full width of the plastid. In the mesophyll chloroplasts, however, there are numerous cylindrical grana consisting of stacks of dense lamellae. The intergrana region is also laminated. The lamellae exhibit a compound structure. It is suggested that lipide layers are linked to a protein layer by non-polar interaction. Chlorophyll is probably distributed over the entire lamellar surface, being held by van der Waals' interaction.

Origin and Intracellular Localisation

Most cellular particles are formed from pre-existing particles. The nucleus is formed by the division of a pre-existing nucleus, in the somatic cells of higher plants and animals by the process of mitosis and in many protozoa by amitosis. In the germ cells meiosis occurs whereby each gamete receives half the number of chromosomes possessed by the adult of the species. The nucleus may be peripheral or central in position.

It is now generally accepted that mitochondria are also self-duplicating particles, Mitochondria-like particles have been known to differentiate into plastids but no evidence has been found for the development of chloroplasts from mitochondria.

Mitochondria have been observed aggregated adjacent to the nucleus and to the outer cell membrane. Light has been shown to affect the localisation and although protoplasmic streaming may play a role in the distribution, mitochondria have a certain independent motility.

The number of mitochondria varies from tissue to tissue and is greater in highly active cells. Even in one cell there may be a fluctuation under different physiological conditions. A diminution occurs after gastrulation and during tissue regeneration, and there is a redistribution during mitosis. The number of cristae within the mitochondrion varies from a great number in cardiac muscle cells to very few in plant mitochondria. Sarcosomes are larger and more numerous in muscles subjected to continuous action such as heart, diaphragm and flight muscles.

Microsomes, sub-microscopic cellular particles, have been isolated by biochemical techniques. The origin of these microsomes is at present uncertain, it seems they may be fragments of the endoplasmic reticulum, most probably of the rough surfaced vesicles.

Chloroplasts develop only from pre-existing chloroplasts or proplastids. The conversion of leucoplasts into chloroplasts has been demonstrated (Wolken and Palade, 1953). The reproduction of the proplastids and the number of these which develop into chloroplasts is regulated.

Chemical Composition and Biochemical Activities

The nucleus contains 100 per cent of the DNA, 12 per cent of the ribose nucleic acid (RNA) and 15 per cent of the total nitrogen of the liver cell. The role of the

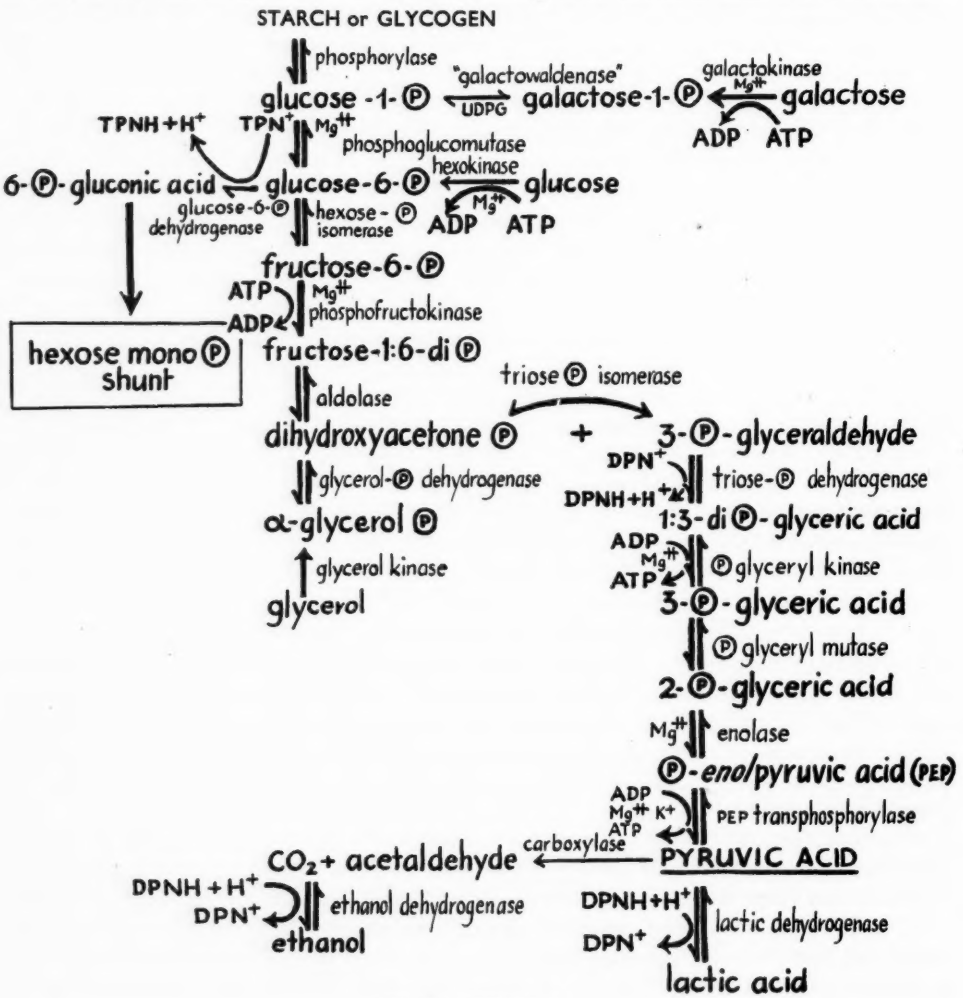

Fig. 1.—Glycolysis.

nucleus in cell metabolism is still controversial. It is possible that sharp localisation of enzymes in the nucleus does not occur. However, the Kornberg enzyme responsible for the synthesis of diphosphopyridine nucleotide (DPN) from nicotinamide mononucleotide and ATP is localised exclusively in the nucleus suggesting that this structure may be a centre of coenzyme or nucleotide formation. Ribonucleic acid may be synthesised here and the phosphorylation of the uridine coenzymes, uridine diphospho glucose (UDPG) and uridine diphospho acetyl glucosamine, by reactions analogous to the following UDPG + pyrophosphate → uridine triphosphate + glucose-1-phosphate, occurs in the rat liver nucleus. The nucleus is involved in protein synthesis (Mirsky *et al.*, 1955) and the nuclei of wheat germ contain glycolytic enzymes. Adenosine triphosphatase (ATPase) and adenosine phosphatase appear to be present and, contrary to the findings of Hogeboom and Schneider, nucleoside phosphorylase and adenine deaminase have been reported in high concentration by Stern *et al.* (1952).

Mitochondria account for 28 per cent of the total nitrogen of the rat or mouse liver cell. The protein content of mitochondria is about 65 per cent of their dry weight. Most of the soluble nitrogen is in the form of proteins, especially globulins. Mitochondria are characterised by a high concentration of lipid and phospholipid (25–30 per cent of the dry weight) and RNA accounts for approximately 0·5 per cent of the dry weight. The coenzymes detected include coenzyme A (CoA), lipoic acid, thiamine pyrophosphate, diphosphopyridine nucleotide, triphosphopyridine nucleotide (TPN), flavin adenine dinucleotide (FAD) and the cytochrome system. The flavin-linked enzymes are strongly bound to the mitochondrion. Mitochondria possess an array of vitamins including pyridoxine (B_6), cobalamin (B_{12}), riboflavin, folinic acid and pantothenic acid. The inorganic ions which are present include potassium, magnesium and phosphate.

It appears that the structure complexity of the mitocondrion is reflected in its biochemical properties. Enzymes present in the mitochondrion may be in the soluble state (or in very labile linkages) or attached to the structural framework. This implies a highly organised arrangement of enzymes within the mitochondrion. Some of these enzymes will be discussed later.

The microsomal fraction accounts for 20–25 per cent of the total nitrogen of the rat or mouse liver cells. This fraction possesses a high concentration of ribose nucleic acid and phospholipid (40 per cent of the dry weight of microsomes is lipid). The high concentration of RNA is related to protein synthesis; the rate of incorporation and the total incorporation being higher in this, than in any other fraction.

Among the enzymes detected are glucose-6-phosphatase, lactonase, DPN- and TPN-cytochrome reductase, esterase, uricase and DPN nucleosidase. Apart from glucose-6-phosphatase and lactonase these enzymes are also present in other fractions. A haemochromogen, cytochrome *m*, involved in the transfer of electrons from DPNH to cytochrome *c* is present in liver microsomes. The accessory role of the microsomes in glycolysis, in Krebs cycle reactions and in fat metabolism will be discussed later.

The Golgi apparatus comprises only 5 per cent of the total tissue nitrogen and contains a high concentration of phospholipid, RNA, and acid and alkaline phosphatases. The system may be concerned with lipid absorption and in the segregation or removal of water from secretory granules.

The submicroscopic secretory granules isolated from milk (Morton, 1954) were lipoprotein complexes containing alkaline phosphatases, xanthine oxidase, diaphorase and DPN cytochrome *c* reductase, as well as unidentified nucleic acid and haemochromogens. The droplets occurring in kidney cells after injection of protein (Strauss, 1954) may be analogous to lysosomes. Granules of 0·15–0·84 μ diameter isolated from lysosome-rich fractions of rat liver are bounded by a semi-permeable membrane and possess acid phosphatase, ribonuclease, deoxyribonuclease, cathepsin,

glucuronidase and ferritin ion. The exact origin of these granules is uncertain, they may represent phagocytosed or pinocytosed material.

It is becoming increasingly apparent that although certain elements may possess some degree of functional autonomy they are mutually dependent on one another in the metabolism of the whole cell. Although over 50 per cent of the glycolytic activity of the cell lies in the soluble fraction the breakdown of carbohydrate to pyruvate requires the integrated activity of several cell structures. It has recently been shown that certain glycolytic enzymes are present in the mitochondria of kidney cells (Kaplan *et al.*, 1951) and in the nucleus of wheat germ. Glucose-6-phosphatase is of microsomal location and glucose-6-P dehydrogenase also appears to be particulate. It is probable that there are soluble and insoluble forms of hexokinase and that the greater portion is localised on mitochondria by a labile linkage.

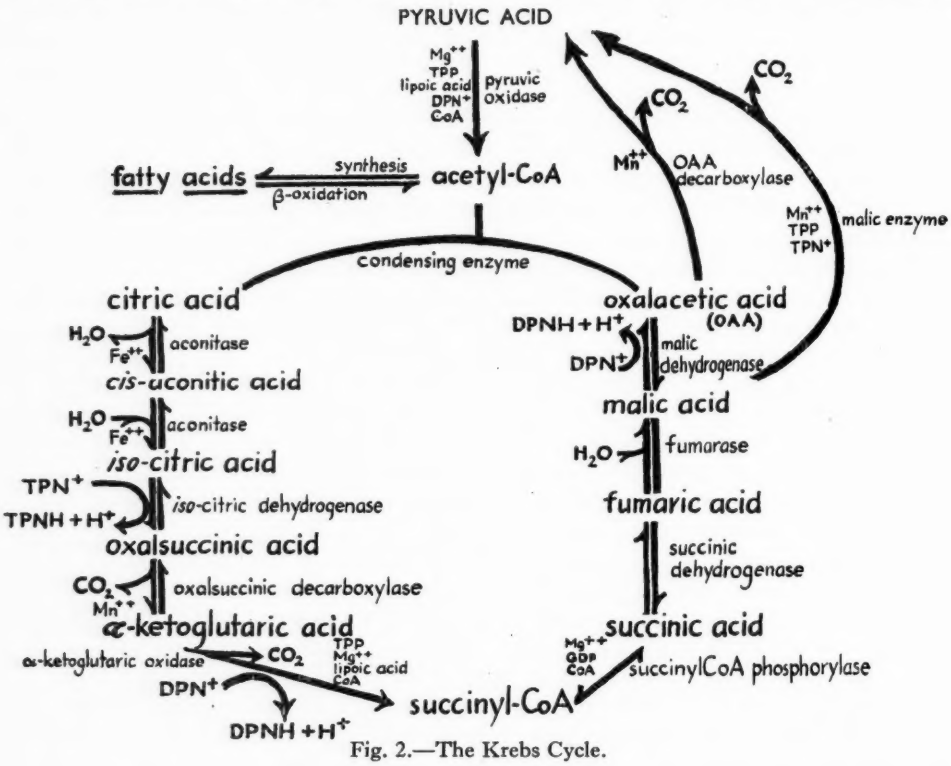

Fig. 2.—The Krebs Cycle.

Present data show that the enzymes of the Krebs cycle are present in the mitochondrion. However, quantitative assays of the distribution of these enzymes indicate that some, notably isocitric dehydrogenase and aconitase, are predominantly associated with the soluble fraction. DPN and TPN specific isocitric dehydrogenase, malic dehydrogenase and the malic enzymes are all present both in particles and in solutions. Also, the enzyme system oxidising α-ketoglutarate may not be localised exclusively in the mitochondria (Siekevitz, 1952). These findings strengthen the concept of intracellular interaction and mutual dependence of cellular particles.

It is now clearly established that the Krebs cycle is operative in plant and animal tissues. However, the existence of the cycle does not necessarily imply that it is the only pathway of pyruvate oxidation. Recent investigations with micro-organisms (Campbell *et al.*, 1953; Wheat and Ajl, 1954; Cleland and Johnson, 1954) indicate the existence of alternate or modified cycles which involve the splitting of a C_6 acid into a C_4 acid and a C_2 acid.

As metabolites are oxidised, electrons are transferred to molecular oxygen via

the electron transport system, which involves a series of reversibly oxidised and reduced intermediary carriers. The principal elements in the sequence appear to be the pyridine nucleotides DPN and TPN, the cytochrome reductases, cytochromes and cytochrome oxidase. The iron-containing flavin molecules, DPN- and TPN-cytochrome *c* reductase are associated with the mitochondria, microsomes and soluble enzymes of the cytoplasm. Cytochromes *a*, *b* and *c*, and cytochrome oxidase are localised on plant and animal mitochondria. In fungi also, cytochrome oxidase is particulate.

In animals and probably in plants there are a number of pathways of electron transport from the substrate to molecular oxygen. Cytochromes b_3, b_4 and b_5 have recently been described in a variety of tissues. Cytochrome *m* (absorption 550–565 mμ) has been found in liver microsomes and can be reduced by DPNH. In many plants the cytochrome *b* and *c* bands appear fused into a single band at 550–565 mμ suggesting a similar component is present in plants.

Although cytochrome oxidase is the general terminal oxidase of animal and plant respiration, alternate pathways of electron transport may be operative in certain plants, for example, cytochrome *b* can transfer electrons directly to oxygen. It has been suggested that polyphenol oxidase, ascorbic acid oxidase and glycolic acid oxidase, are functional as terminal oxidases. The major portion of these three enzymes is present in the soluble fraction, while a small amount is particulate.

Of the energy liberated in the conversion of glucose to carbon dioxide and water, by far the greater portion is released during the aerobic phases of respiration. Energy liberated during the passage of electron equivalents from substrate to oxygen is conserved as ATP, by the process of oxidative phosphorylation. During the oxidation of pyridine nucleotides, flavin nucleotides, the cytochrome system and substrate, in the case of α-ketoglutarate, inorganic phosphate is esterified and ADP is converted to ATP.

It is characteristic of intact mitochondria that more than one mole of phosphate is esterified for every atom of oxygen consumed. The oxidative reactions of the Krebs cycle are characterised by P/O ratios[1] approaching three, with the exception of the oxidation of succinate (P/O *ca.* 2) and of α-ketoglutarate (P/O *ca.* 4). Mitochondria of plants also appear to be the loci of phosphate esterification reactions similar to those in animal tissues. The extreme lability of the phosphorylative mechanisms and the isolation procedures employed have hindered the widespread demonstration of oxidative phosphorylation in micro-organisms but the process has been demonstrated in yeast (Linnane, 1956).

Certain substances uncouple oxidative phosphorylation, probably by dephosphorylating the primary acceptor complex before the phosphoryl group can be transferred to ADP. Amongst the well-known uncoupling agents are 2,4-dinitrophenol (DNP), gramicidin, aureomycin, atebrin, thyroxin (Maley and Lardy, 1955) and ionising radiations.

Several cell fractions appear to be involved in fat metabolism. Each of the enzymes responsible for the five known steps in fatty acid oxidation has been isolated from a mitochondrial preparation of the liver cell and certain of these enzymes have been demonstrated in plants. The formation of acetyl-CoA, a central metabolite in the synthesis and breakdown of a variety of substances, has been demonstrated in animal and plant mitochondria. A fatty acid oxidation system active towards long chain fatty acids has been reported associated with the microsome fraction from germinating peanut cotyledons (Newcomb and Stumpf).

In the liver, mitochondria, together with a soluble fraction, appear to be necessary for fatty acid formation, which has been postulated to occur by the reversal of the oxidative sequence. In the mammary gland, on the other hand, fatty acid synthesis

[1] $\text{P/O ratio} = \dfrac{\text{moles of orthophosphate taken up.}}{\text{atoms of oxygen consumed}}$

appears to be independent of mitochondria. The formation of phosphatides in the liver involves the collaboration of mitochondria and a cytoplasmic factor.

Cholesterol metabolism involves the soluble fraction in conjunction with microsomes. Free cholesterol is localised mainly in the microsomes of liver tissue and likewise cholesterol esterase, whereas esterified cholesterol is present in the soluble fraction. Steroid metabolism also occurs in several fractions. The hydroxylation of deoxycorticosterone is carried out by adrenal mitochondria, while the oxidation of progesterone is catalysed by the soluble fraction.

The many enzyme systems required in the metabolism of proteins also seem to be distributed in a variety of cellular fractions. Incorporation of amino-acids into proteins appears to be a function of the microsomes but is controlled by the availability of energy produced by the mitochondria. It seems likely that the oxidation and synthesis of amino-acids are localised in plant and animal mitochondria. This plant fraction contains the major portion of glutamine synthetase (Webster, 1953) and glutamic dehydrogenase (Smillie, 1955). Transamination, transpeptidation and certain amino-acid interconversions, e.g. glutamic acid from proline, are localised in the mitochondrial fraction. The enzyme system responsible for glutathione synthesis is bound by a rather labile linkage to the mitochondria. The mitochondria presumably provide the energy to enable the microsomes to synthesise protein whilst the nucleus apparently can perform this function unaided.

The nucleus has been proposed as the centre of coenzyme or nucleotide formation. The Kornberg enzyme responsible for the formation of DPN is localised exclusively in the nucleus. Phosphorylation of the uridine coenzymes occurs in the nucleus and certain stages in RNA metabolism have been identified in mitochondria, in the soluble fraction and in the nucleus. Ribonuclease and deoxyribonuclease, responsible for the hydrolysis of RNA and DNA respectively, are present mainly in the mitochondria, while nucleoside phosphorylase and adenosine deaminase involved in purine metabolism are associated largely with the soluble fraction.

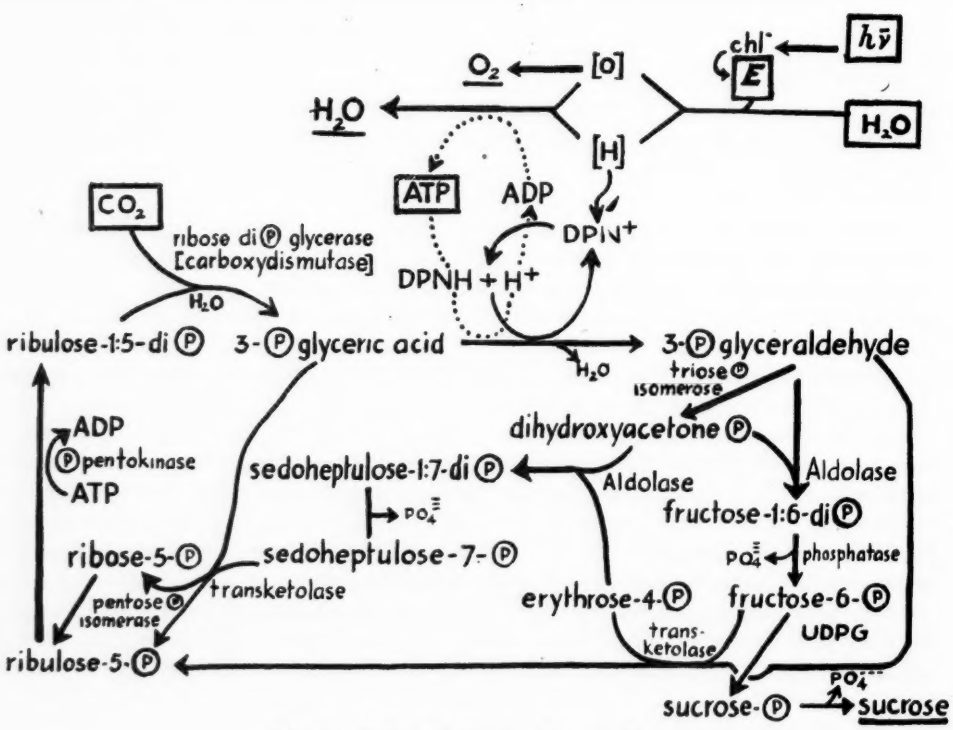

Fig. 3.—Path of carbon in photosynthesis.

Certain detoxification reactions have recently been localised. The microsomes are implied as the site of demethylation of certain azodye carcinogens, dealkylation of a large number of compounds, deamination of amphetamine and the oxidation of barbiturates. In addition, a soluble fraction and TPN are required.

The chloroplasts, present in certain cells of green plants, are composed of protein, lipid, chlorophyll and carotenoids. Among the mineral constituents are phosphorus, calcium, sodium and a little iron and copper. Starch may be present especially after periods of intense photosynthetic activity. The chloroplast is the site of photosynthesis, the photochemical splitting of water to hydrogen and oxygen, CO_2 is reduced by the hydrogen to the level of carbohydrate and oxygen is liberated in its molecular form. The process may conveniently be subdivided into two general sections: the first involves the chemical transformations in which the carbon atom of CO_2 enters carbohydrate (Figure 3), and the second deals with energy considerations.

This entire cycle has been carried out by isolated chloroplasts and in a soluble system free of organised cell structures.

Light energy absorbed by chlorophyll, *a*, *b*, *c*, *d*, carotenoids, xanthophyll, phycoerythrin and phycocyanin is transferred to chlorophyll *a* molecules. The exact mechanism of the conversion of light energy into chemical energy is not completely understood. Lipoic acid has been proposed as the quantum conversion agent. It is suggested that as the excited chlorophyll molecule returns to the ground state, energy is transferred to break the S—S bond giving a diradical which reacts with water (Figure 4).

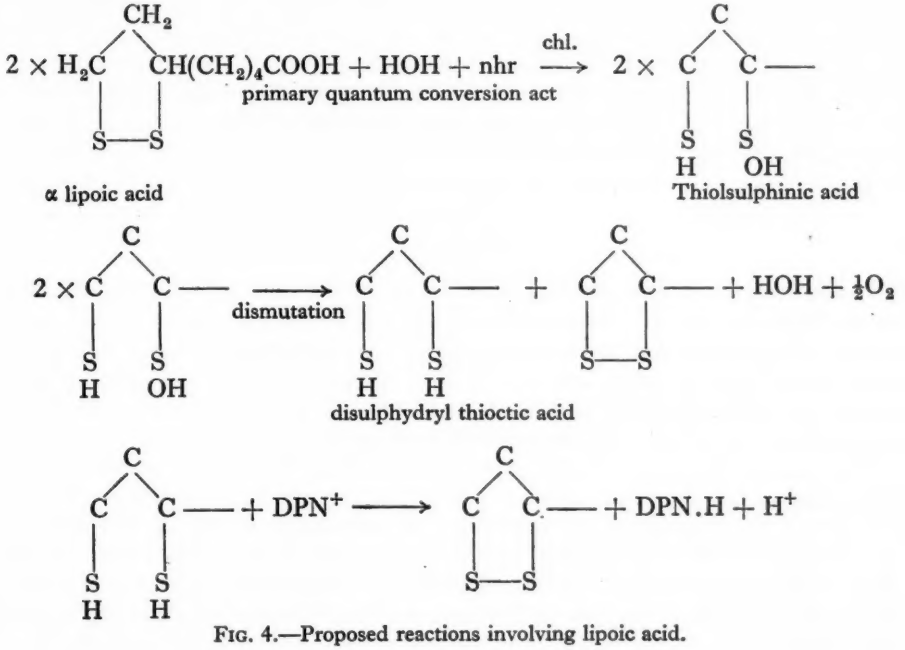

FIG. 4.—Proposed reactions involving lipoic acid.

A photosynthetic phosphorylation scheme has been proposed whereby ATP is formed during the transfer of hydrogen, as in oxidative phosphorylation. Vitamin K and cytochrome *f* appear to be involved in addition to the better-known nucleotides, flavins and cytochromes. Isolated grana are capable of carrying out photosynthetic phosphorylation.

The entire reaction of photosynthesis probably occurs in the chloroplasts. Since the enzymes of the carbon reduction cycle are rather sensitive, they may not be

part of an organised structure but perhaps are merely enclosed in the chloroplast. On the other hand, the apparatus for the absorption of light, its conversion into chemical energy and related processes is rather resistant to inactivation indicating that an organised enzymatic system is involved. A close association between mitochondrial and chloroplastic activities is suggested by the aggregation, in the light, of Euglena mitochondria around the chloroplasts (Wolken and Palade, 1953).

Mitochondrial Regulation of Physiological Activity

Energy requiring processes will be dependent, either directly or indirectly, on mitochondrial metabolism. Increase in respiratory rate has long been known to attend the performace of work. Normally the rate of respiration is controlled by the capacity of the phosphorylative system. The uncoupling agent DNP may be used to ascertain the extent of this limitation; respiratory rate is increased in active tissues and is not further increased by DNP. In this way a number of physiological processes have been shown to be dependent on mitochondrial metabolism.

The process of fruit ripening appears to be controlled by coupled phosphorylation. An energy source is essential for the maintenance of the water balance of animal mitochondria, and in plant cells, a mechanism, which may be related to ATP generation, is needed to secrete water from the outside into the vacuole. Certain functions of the renal tubule, in particular, active transport systems, can be abolished by uncoupling of oxidative phosphorylation.

Many other processes, including growth, glucose absorption, salt accumulation, cell division and tissue differentiation, also depend on a supply of energy.

Mitochondrial oxidative activity is correlated with the colour of vertebrate muscles. Red muscles, those with a high myoglobin content, are capable of continuous activity, whereas pale muscles are capable of sporadic bursts of activity. In insects, there occurs a physiological and biochemical differentiation between high frequency muscles, characterised by little endoplasmic reticulum and numerous large mitochondria, and low frequency muscles with fewer mitochondria and whose oxidative capacity and colour are proportional to the quantity of mitochondria.

Conclusion

The application of improved techniques in microscopy and histochemistry has shown that the cell is a complicated mosaic of structural units. These particles possess a high degree of structural and functional organisation, and although they are endowed with a certain degree of autonomy they are mutually dependent in the overall activities of the cell. The particulate nature of the protoplasm has been demonstrated in plants, animals and micro-organisms.

The internal structure of certain particles, such as the nucleus, mitochondria and chloroplasts, has been revealed. These particles are surrounded by a limiting membrane, which is about 27 mμ thick in the case of mitochondria. The assumption of a semi-permeable membrane would best explain certain biochemical observations. Mitochondria accumulate numerous ions and small organic molecules and retain many soluble proteins including a variety of enzymes. A highly organised arrangement of enzymes within the mitochondrion seems to be implicit.

Enzymes which are firmly bound to the structural framework of the mitochondrion include succinic dehydrogenase, DPN-cytochrome *c* reductase, cytochrome oxidase, cytochrome *c*, ATPase and uricase. Amongst the enzymes present in soluble form are glutamic dehydrogenase, adenylate kinase and fumarase. It seems that the localisation of enzymes within the mitochondria permits the orderly sequence of biochemical reactions to proceed. Mitochondrial integrity and correct orientation of enzymes is necessary for complete enzymatic activity. Thus hypotonic solutions lead to swelling and disruption of certain enzymes, while hypertonic

solutions cause destruction of oxidative phosphorylation. Succinoxidase and fumarase are resistant to such maltreatment.

Although specific cellular structures possess specific chemical properties there is a considerable amount of interaction between particles. This requires strategic intracellular localisation of these structures so that their individual activities can be efficiently integrated. Glycolysis involves the soluble fraction, mitochondria, the nucleus, and the plastids in the case of plants. DPN produced in the nucleus is required as a coenzyme by the cytoplasm. Similarly, ATP produced in the mitochondria by oxidative phosphorylation is utilised at the site of production and elsewhere, for synthetic and other energy-consuming processes. Mitochondria may interact with the chloroplasts in photosynthesis. Although mitochondria, plastids and the cytoplasmic particles may be endowed with genetic continuity, a continuous interaction of nucleus and cytoplasm is essential during reproduction and development.

The experimental evidence now available portrays the cell, as limited by a cell membrane and containing within the protoplasm an array of particles. These particles possess a high degree of structural organisation and are characterised by certain biochemical activities. The interdependence of the various structures highlights the cell as an integrated unit which can only be broken down for the purpose of analysis.

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ANCIENT AGRICULTURE IN IRELAND AND NORTH-WEST EUROPE

AT THE Dublin meeting of the Association the morning of September 9, 1957, was given over to a symposium on ancient agriculture in Ireland and North-Western Europe. The emphasis was on the study of fields. The following brief note of the proceedings prefaces much shortened versions of the original talks.

Mr. H. C. Bowen, of the Royal Commission on Historical Monuments (England), began with a paper which attempted to analyse the nature of ancient field remains in England, to indicate the sort of information they could reasonably be expected to yield, and, assuming that this was valuable, to urge the need for concentrated research before the evidence was destroyed. In particular he pleaded for the formation of a panel to consider how this work could best be done. The President of the Section, Professor Hawkes, gave his support. (The Council of the Association has now agreed to sponsor the formation of a committee with this object.)

Mr. F. A. Aberg was next due to give a paper introducing the study of ancient ploughs and plough irons. He had most unfortunately to be admitted to hospital just before the meeting and his paper was read by Mr. Bowen. It set out to sum up all the available evidence, including some of Roman date from eastern Austria which, though stretching the geographical limits of the discussion, was too important to omit.

Dr. V. B. Proudfoot, of the Nuffield Quaternary Research Unit, Queen's University, Belfast, summarised the evidence for ancient fields in Ireland. Although relatively meagre, the evidence was important, for some fields of Neolithic and Early Bronze Age date could be recognised. For the Dark Age and early historic periods literary sources could supplement the archaeological material, thus revealing a picture of settled agriculture very different from that often supposed.

M. Pierre Flatrès, Chargé des Recherches du Centre National de la Recherche Scientifique, Rennes University, was also very unfortunately unable to be present owing to illness. A summary of his paper is included below. It analyses the features of agricultural life and settlement in the (modern) Celtic regions, stresses the significance of field patterns, but also finally hints that the traditions he has been studying might in fact be the heritage of an Atlantic rather than a specifically Celtic civilisation.

Professor M. V. Duignan introduced the discussion. He concentrated on the Irish evidence, emphasising that only a portion of the potentially valuable literary and legal evidence has been satisfactorily published and that a detailed comparative study of Welsh and Irish literature should be very profitable. He noted an interesting paradox in that the name for the plough in the early Irish laws signified 'ard', or light plough, while in fact remains of heavy ploughs are known, and in areas which tend to confirm G. F. Mitchell's suggestion of greatly increased forest clearance at the beginning of our era. The name for a plough-team 'seisreach'—a derivative of the numeral 'se'—was also an interesting fossil.

Professor Estyn Evans, among other points, expressed a dislike of the continued use of the term 'Celtic fields', noting that it could not be supported by any reference to the modern pattern in Celtic countries, much of which was a development of the last few hundred years. He considered that, despite the lack of positive evidence (largely due to the later expansion of upland bog and the intensive cultivation of the lowlands), much of the land was never permanently enclosed.

Captain O'Danachair, of the Irish Folklore Commission, stressed the importance of the Irish spade as opposed to the plough. He also noted the impermanence of at

least some old boundaries, citing those of wattle depicted on contemporary maps of the wars of Elizabeth I in Ireland.

Mr. Lucas, Director of the National Museum, Dublin, pointed out that the early Irish Laws describe wattle fences as normal.

The President, Professor Hawkes, in his concluding remarks, heartily supported Professor Evans in his attack on the undoubted misnomer of 'Celtic' fields, adding to previous arguments the point that they could not by any means be assumed to originate in the Late Bronze Age.

THE STUDY OF ANCIENT FIELDS (WITH SPECIAL REFERENCE TO ENGLAND)

By

H. C. Bowen

(*Acknowledgment*: Much of the following derives from experience gained in the service of the Royal Commission on Historical Monuments (England), to whom I am greatly obliged for permission to refer to some material as yet unpublished, but the opinions I express are not necessarily any but my own.)

Taking England as a whole the remains of ancient fields still cover a much larger area than any other form of earthwork. They are being levelled at a rate and in a way which is going to end, before many years have passed, in virtually complete destruction. It is therefore particularly important that an urgent assessment be made now of: (*a*) what we know; (*b*) what we should still like to know; (*c*) what in fact is recoverable from a study of the fields, and (*d*) by what methods we should seek to get our answers. If we decide, as I think we should, that examination on the ground is necessary, then the task needs many people working on carefully considered lines with specific objectives in view. It is in any case only in this way that we can hope to make substantial advances in our knowledge.

Their study is the study of past countrysides, a topographical palimpsest, the phases of which need deciphering; its potential results include a much fuller knowledge of distribution, the location of settlements (to which the fields often give the best clues) and of farm boundaries, the identification of field types (if not attribution), the discovery of very early fields (before the Late Bronze Age) and the recognition of post-Roman fields, and to some extent information on the intangible things such as attitudes of mind, e.g. towards burial mounds (almost, if not always, carefully respected in the Iron Age in England).

Our present knowledge is limited. A statement shows in each succeeding point a greater element of doubt. Thus:

(*a*) 'Celtic'[1] fields, as generally understood, represent the remains of settled agriculture so far dated (despite the other evidence for some sort of agriculture in Neolithic times and onwards) from the Late Bronze Age into the Roman period. Though found elsewhere (sometimes in large concentrations as in Upper Wharfedale, Yorkshire [2]) they are still most numerous on the downland of southern England, where they are found on 'clay-with-flints' as well as the lighter soils. In the Fens a cognate pattern of cropmarks seems to belong entirely to the Roman period.

(*b*) Even in a general sense they are difficult to date unless associated (as all too rarely) with a recognisable earthwork, preferably a settlement. Mere physical

[1] The writer uses the well-known term 'Celtic' fields here solely because he still cannot think of an alternative which would be sufficiently imprecise and yet accurate.

[2] See especially: *Yorks. archaeol. J.* **33** (1937), p. 166.

contiguity is not necessarily proof of contemporaneity.[1] Ironically, no fields were preserved around the classic Iron Age 'A' site of Little Woodbury.

(*c*) Abraded potsherds, frequently Romano-British, sometimes Iron Age or Late Bronze Age, scattered on the fields, doubtless came from miskins. They are often important but the lack of other pottery is poor evidence for absence of cultivation at a different phase, when manuring was not used or, simply, did not depend on farmyard rubbish heaps.[2]

(*d*) In parts of Wessex there are long stretches of banks and ditches. Some of these clearly bound blocks of fields and presumably act as stock fences. Elsewhere, great contiguous blocks of fields leave no room for permanent pasture.

(*e*) Close examination of 'Celtic' fields shows a considerable variety and except in a very general (perhaps misleading) sense it is not possible to talk of 'typical Celtic fields'.

(*f*) Much of the downland, more than usually allowed, bears the marks of ploughing in a relatively late period. This is often mixed up with 'Celtic' fields, usually too small to satisfy these later farmers, and so the lesser boundaries are ploughed over (and out) leaving the high lynchets to preserve a false 'Celtic' pattern.

How then, can we hope to resolve the problems implicit in the above? The first thing is to account for (*f*)—the 'post-"Celtic"' farming. This is most obvious when marked by:

(i) Narrow (2 to 5 yards wide) plough ridges found in compact blocks;
(ii) broad plough ridges ('broad-rig'—an arbitrary 6 yards or more wide);
(iii) flat strip terraced fields ('strip lynchets').

I do not think there is any mystery about (i) which, despite descriptions of narrow 'stitches' as early as the sixteenth century,[3] mostly belongs to the eighteenth and nineteenth centuries. By (iii) I mean fields of the type well known in medieval association, which I do not feel inclined to put before the Saxon period merely because distant from a village, and also because I think there are scarped strip fields of an earlier period distinguishable especially by square ends, unusual in the later fields. Although (ii) 'broad rig' is often found with 'strip lynchets' in contemporary association I regard it as a dating problem still to be resolved when found in remote areas, sometimes crossing present-day parish boundaries, especially since by its nature it is the indistinguishable product of a two-way plough (of a sort known to exist in Roman times, however rare, though well known in all later periods). Crawford and Keiller illustrated some examples of it in *Wessex from the Air* but Curwen was the first to suggest very tentatively that in some cases it could be medieval.[4] When superimposed on 'Celtic' fields it can be very misleading and has been responsible for some mistaken ideas on 'Celtic Strip fields'.[5]

A site west of Dorchester, Dorset (described as illustrative of at least eighteen large areas between there and Marlborough in North Wiltshire), by its situation cannot be Belgic or pagan Saxon and its closeness to Romano-British settlements is no proof that it belongs to them.[6]

Once the 'intrusive' elements are allowed for, the field remains still provide a challenge: *inter alia* to be used as guides to their farms—some of which are certainly

[1] Cf. the plan of settlement and fields at Plumpton Plain, Sussex (reproduced by E. C. Curwen, *Plough and Pasture*, fig. 9).

[2] It seems to me that the lack of significant pottery from recent excavations of strip lynchets stresses this point, c.f. Peter Wood, *Wiltsh. archaeol. nat. Hist. Mag.* **56** (1955), p. 15.

[3] E.g. William of Folkingham, *Feudigraphia* (1610), p. 48.

[4] *Wessex from the Air*, pp. 124, 128, 131, 140; *Proc. prehist. Soc.* **4**, (1938), pp. 49–50.

[5] As near Knighton Hill Buildings, Broad Chalke, Wiltshire. Heywood Sumner, *Earthworks of Cranborne Chase*, pp. 43–4 and plate XXII.

[6] For a longer discussion see *Archaeol. News Letter*, **6** (2), (1955), pp. 36–8.

very different from Little Woodbury in lay-out and size, to show farm boundaries —whether dividing twin blocks of fields (a 'two-field system') or separating two farms, to be broken down into types and into phases illustrating trends of development.

To meet the challenge of destruction, assuming that the worth-whileness of research is accepted, I would suggest the formation of a panel to consider aims and means and the preparation of a handbook which would set out standards and methods.

INTRODUCTION TO ANCIENT PLOUGHS

A summary of the evidence in Europe

By

F. A. Aberg

The scope of the paper covered only the nature and use of the plough during the prehistoric and Roman periods in Europe.

The evidence can be grouped as follows:

1. Ploughs of wood only.
2. The use of iron plough shares.
3. The appearance of the heavy plough using coulter as well as the share.

Taking first wooden ploughs, the earliest evidence is derived from furrow marks found under Bronze Age barrows in Denmark and Holland [1] and under a farm building of the Early Iron Age in Denmark.

Rock drawings of the Bronze Age in Sweden and the maritime Alps, and actual plough remains from Danish and North German bogs also provide evidence of its use. They show the presence of light ploughs of two types belonging to the group called *ards* (Latin *aratrum*) by the Danes, which were characterised by a symmetrical form, a long beam usually reaching to the yoke, and only one handle. They had no coulter or mould-board.

The first type of ard is distinguished by a horizontal *sole* to which the other parts are subsidiary.[2] The second type is structurally dependent on the *beam*, all its parts fitting into a rectangular hole near the base of this.[3] The share consists of a long narrow upper share resting on a broad arrow-shaped plough-head which projects through the hole in the beam and also forms the handle. There is evidence for its use in Britain as well as on the Continent.

Both types were pulled by oxen, normally a pair, yoked generally to a long beam. Occasionally traces were used and one rock drawing even shows a horse harnessed to the plough by the tail.[4] Hardwoods were used in their construction, and friction marks suggest that the ards were tilted. However, a furrow could not be turned consistently because of the symmetrical share, and fields were usually cross-ploughed. There is evidence that ards were used on heavy soils in Denmark.[5]

In England iron shares provide the bulk of the evidence for actual ploughs, beginning in Iron Age 'A'. Bronze was too soft to make a good plough share, but iron gave longer life and deeper penetration to the plough.

Long, narrow socketed shares appear first in Iron Age 'A' and 'B' contexts.[6] On Belgic and Roman sites broad shares of more varying shapes occur, suggesting some specialisation for different soil conditions.

[1] *Antiquity*, **20** (1946), p. 158.
[2] P. V. Glob, *Ard og Plov* (1951), p. 111.
[3] P. V. Glob, op. cit., p. 93.
[4] P. V. Glob, op. cit., p. 55.
[5] Ibid., p. 124.
[6] *Archaeol J.* **104** (1947), p. 82, and F. G. Payne, *Yr Aradr Gymreig* (1954), chapter 1.

A bronze model from Sussex shows that even very heavy shares could be fitted to ards and illustrates the introduction of ground-wrests by the Roman period. Double wrests were used and the symmetrical form of the plough was unchanged. Tanged as well as socketed shares are known from Iron Age and Roman sites, both here and abroad.

The normal plough is characterised by a coulter and mould-board. Its existence in Roman Britain is proved by the discovery of eighteen coulters from different sites. These may have fitted into a heavy beam supported by a rectangular frame, consisting of horizontal sole, beam, and vertical brace and stilt. The blade of the coulter is often beaten out on one side and two-thirds of those found in England have been flattened in this manner. With these the normal method of ploughing is backwards and forwards in strips. With a fixed furrow-side the share is also asymmetric and three such plough shares have been found in Britain.[1] Furrows made in the second century A.D., by a mould-board plough using a coulter, have been found in Schleswig-Holstein.[2]

There is no evidence from England for a wheel-carriage, as described by Pliny in Central Europe, to support the heavy beam of the normal plough. Evidence to confirm its existence is, however, forthcoming from eastern Austria, where plough-traces (the latest of which are dateable within the Roman period) to link a fore-carriage to a plough beam, have been found.[3]

ANCIENT IRISH FIELD SYSTEMS

By Dr. V. B. Proudfoot

In Ireland there is evidence for fields, or at least for land divisions, from Neolithic times onwards. A few early field boundaries have been securely related to excavated sites. Dark Age and medieval fields are more numerous than earlier, but are still few compared with the number of known settlement sites.

Neolithic and Early Bronze Age agriculture is well attested in Ireland as in Continental Europe. Pollen analyses suggest the clearance and cultivation of small patches of virgin forest for a few years before abandonment to forest again—compare the practices of European colonists in parts of north-east America, or of nineteenth-century cultivators along the forest margins of northern Europe. Identification of cereal impressions on datable pottery, and the study of animal bones from excavated sites, have demonstrated the variety and development of prehistoric farming.

Possibly the earliest field banks known in Ireland are at Beaghmore, Co. Tyrone.[4] The site, formerly under 2–6 feet of blanket peat, lies on boulder clay soils at a height of 600 feet, on the eastern flanks of the Sperrin Mountains. Excavation revealed a low bank 170 feet long, built of small stones and earth, overlain by two stone alignments associated with a pair of stone circles. Remains of other similar banks were found on the site and it seems likely that they represent a whole system of fields or plots, dated on the available evidence to Neolithic times.

At Ballygroll, Co. Londonderry, on a broad ridge of boulder clay flanked by two streams, a number of huts and burial sites are uncertainly related to short, straight, intermittent stretches of irregularly set stones, probably bases for sod-built walls. These enclose fields of irregular shape varying from 3–12 acres in extent. It seems likely that fields, huts and burials were broadly contemporary, and were all abandoned before the overlying peat began to form, probably by the middle of the First Millennium B.C.

[1] *Agric. Hist. Rev.* **5** (2), 1957, p. 74.
[2] *Newsletter No.* 2, International Secretariat for Research on the History of Agricultural Implements.
[3] *Laos*, **2** (1951), p. 51.
[4] A full bibliography is given at the end of this paper.

Similar imprecise dating is available at Castledamph, Co. Tyrone, where peat had covered a rough low bank of large flat slabs running uphill for about 200 yards, which was shown by excavation to lie over, and therefore be later than, a stone circle.

Examples considered so far have been near the present upland limits of cultivation, but one relevant site, at Millin Bay, Co. Down, is on the '25 foot' raised beach. A cairn, probably of late Neolithic date, was built over a narrow stone wall, 18–24 inches wide and 30 inches high. The wall was probably free-standing in an area where dune-like conditions may have prevailed. It can most reasonably be regarded as a field boundary built, like the early field banks already described, to protect the enclosed area from damage by straying animals. Earthen and stone foundation courses probably represent the bases of sod-built walls, or firm foundations for timber fences, intended to guard growing crops. Pioneer farmers in forested North America had similarly to erect fences, particularly against the depredations of deer, who flourished in secondary-growth forest along the margins of cultivation.

Few ancient fields can be definitely associated with raths, the most abundant settlement sites of late prehistoric and early historic times. Aerial photographs suggest that such fields may sometimes have been destroyed by later cultivation, as at Ballyminetragh in Co. Down, but it is seldom possible from air photographs alone to decide the relationships of fields to settlements. Some field banks have almost certainly been incorporated in the present layout, so that only differences in the type or size of bank will betray the probable existence of an earlier field system—as on the slopes of Deehommed, Co. Down, where massive stone field walls, quite distinct from more recent banks, seem to be contemporary with a stone-walled cashel. Similarly, field banks following the contours of a drumlin, on top of which is a rath, may be early boundaries, but no example has been proved by excavation.

In Dark Age or early Christian Ireland, literary sources supplement the archaeological evidence for a settled, well-ordered population. Fields were ploughed, and fenced to protect the wide variety of crops grown. Part of the agrarian economy was based on private property, in land and livestock, but there were also elaborate rules for the usages of common land worked by rent-paying co-tenants, low in the social scale and perhaps closer to serfs than tenants proper. Probably there were two systems of land tenure in operation alongside each other, and it may well be that open and enclosed fields also co-existed. Archaeology reveals a considerable variety of settlement forms, but little definite evidence for associated fields. Direct evidence for tillage is slender, there being few finds of the cereals grown or of their impressions on pottery. Plough coulters and shares suggest a low heavy plough capable of dealing with the heavy lowland soils cultivated for the first time in the First Millennium A.D.

Groups of small rectilineal fields definitely associated with excavated settlement sites of the Christian era have been recorded at Beginish, Cush, Lissachiggel, and Two Mile Stone. On all these sites no field is probably more than 5 acres. It has not yet been possible to use the recognisable field systems to calculate the acreages of individual farms. At Two Mile Stone two cashels and six huts were built on a limestone ridge of 120 acres, but the dwellings may not be strictly contemporary. Rath farms presumably cultivated isolated drumlins on which they were built, the contour fences of which may have enclosed a continuously tilled infield of 12–20 acres.

There is nothing to show how long these fields continued in use, but survival into the medieval period is suggested by such sites as Caherguillamore, Co. Limerick, where rectangular huts of fourteenth to sixteenth-century date probably succeeded the earlier raths. Huts and raths are incorporated in an elaborate field system, presumably in use for a considerable period. Similar conditions on a

smaller scale have been noted at Ballymoneymore, Co. Antrim. Small square fields akin to those at Cush have been mapped at Goodland, north Antrim, where field boundaries are overlaid by several huts, probably of late medieval date.

The problems on this and other sites can only be solved by further excavation aimed at obtaining a more detailed history of early field systems in Ireland

I am indebted to Professor E. E. Evans, Mr. E. M. Jope and Mr. H. J. Case for helpful discussion on these problems.

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RURAL PATTERNS IN CELTIC COUNTRIES

A Comparative Study

By Pierre Flatrès

Only the old native patterns of present Celtic countries will be described. Brittany, where no non-Celtic colonisation has taken place, is an excellent guide to what is really native.

The difference between the native patterns springs mainly from the opposition between the old tribal and pastoral tradition of Wales, Ireland and Scotland, and the arable tradition of Cornwall and Brittany.

Agricultural systems

Two features are common to all Celtic countries:

(*a*) *Variable intensity of cultivation* depending on the relative fertility of the farm soils.

(*b*) *Periods of continuous cropping* alternating with more or less long periods of fallowing.

Eighteenth-century authors illustrate many variations of four represenative conditions:

(i) Exceptionally, continuous cropping of cereals without a break.
(ii) In lands of ordinary fertility alternating periods (7–10 years) of crops and fallow.
(iii) In less fertile lands, longer fallow.
(iv) On the worst soils, an occasional crop every 10 or 20 years.

In some countries, however, there was a firm distinction between intensely cultivated land and the rest. In Brittany, the first ('terres chaudes') were opposed to the 'terres froides' bounding the 'landes' which produced only occasional crops. In Scotland the distinction between 'infield' and 'outfield' was even stronger. In both countries it was probably legal in origin, but in fact the distinctions drawn were not rigid.

In the British Isles the crop plan was usually a monotonous run of potatoes or oats. Brittany, by contrast, had evolved a complex rotation. Here, fodder crops introduced to replace gorse—once deliberately grown on fallow land—led to the modern agricultural system (without fallowing).

Settlement pattern

The settlement pattern in all Celtic countries is characterised by the presence of two types of settlement: isolated farms, and small clusters of farms (or villages).

The distinction is not always clear-cut and all shades of variation are found.

Sometimes there is a development in which one type changes into another, as when isolated farms are divided between heirs or are added to by newcomers, and become villages, or when villages are depopulated to the level of farms. Evolution along these lines is probably made possible by the absence of large villages, and this in itself appears to be linked to a most important feature in Celtic countries—the small village territories.

Field patterns

Field patterns comprise two sorts. The first, of *open fields*, occurs when two or more farmers have strips not separated by fences. The second consists of *enclosed* fields. Again, there are all shades of variety, for instance:

(*a*) Some strips are separated by boundary stones, others by balks that might resemble small banks.

(*b*) Enclosed fields are sometimes divided between heirs in unfenced strips. On the other hand, open-field strips may be individually enclosed to make long, narrow and sometimes curved fields (conveniently called 'striped fields' or 'champs lanières').

Open fields in Celtic countries are often surrounded by a boundary bank which divides them from the enclosed fields or waste. Open fields so circumscribed are called 'mejou' in Brittany.

It is generally impossible to find on the ground an example of a two- or three-field system. (The Breton islets of Houat and Hoédic provide exceptions, and George Owen might have been describing something of the sort on the peninsula of Dinas in sixteenth-century Pembrokeshire.)

In sum, Celtic open fields are very diverse. The size of the open-field groups is very variable, while the size and shape of the individual strips is also far from constant.

In the Irish 'rundale' system the emphasis was on a very minute division of the ground between partners, in conformity with the old tribal tradition of fractional division of tribal rights. The use of the spade enabled the Irish to carry this minuteness to an extreme. Sometimes the strip was reduced to a mere one or two 'iomaire' ('lazy beds') of 1·5 m. wide and a few metres long.

Though open fields usually belong to villages there are two exeptions: the one, ancient, is in Wales. (The other, in Brittany, is modern.) In Wales the scattered farms of the free tribes shared strips in open field situated more or less centrally in the tribal territory. Clear examples of this survived in some remote Merionethshire valleys long enough to be shown on the tithe maps (Llandrillo and Llanymawddwy). Even today the farms of the two valleys of Garthbeibio (Montgomery)

share moorland strips on the waste (Y Waun Oer) between them, and still cut hay on those strips. This notable exception to a general rule is certainly due to the strength of the tribal links in ancient Wales, enabling farmers to have some collective organisation without a village community.

Enclosed fields probably always existed side by side with open fields; nevertheless, what has caused Celtic countries to be described so often today as typical enclosed-field areas is really the process of enclosure in recent centuries. Historically, there is evidence for enclosure in Cornwall as early as the thirteenth century, and in some places enclosures were predominant by the seventeenth century.

There are two types of enclosed fields, irregular and regular. The first is virtually confined to rugged districts and is rare in Brittany.

Regular fields are usually quadrilateral. The most convenient for the plough are of such proportions as will obviate too frequent turnings at the end of the field. Calculations based on many examples show that rectangles one and a half times as long as broad are the most favoured. In some pastoral areas a more compact figure with rounded angles and therefore shorter 'fences' is often preferred. The size of regular fields is very variable and often dependent on the size of the farm.

The regular fields, because of their very regularity, must be laid out according to certain patterns.

(*a*) *Determined by the relief*, tending to follow contours and lines of greatest slope.

(*b*) *Consequent upon encroachment*: these usually have a rounded boundary facing the waste for reasons both practical (involving shortest fence-line for a given area) and psychological (less obtrusive and therefore less likely to be challenged by users of the waste). In cases of successive encroachments the farms may then be surrounded by a series of circular or semi-circular lines of acquisition, each zone being divided into fields.

(*c*) *Orientated.* A pattern of a kind, in parts of Devon and Cornwall, already studied by Professor Meynier in Brittany,[1] the main lines of the fields parallel and usually orientated slightly east of south. I believe this originates in the lie of the farmhouse, facing south to get the sun and slightly east to avoid the main impact of western storms.

All the patterns here described, though very different from the rural patterns in the English and Parisian lowlands, are not confined to Celtic countries. Rather are we beginning to recognise an Atlantic rural civilisation extending along the western fringe of Europe, 'O'Breatain Leatha Co Lochlaind agus o'insibh Orc Co Espain'—'from Brittany-Armoric to Scandinavia and from the isles of Orkney to Spain'.[2]

[1] 'Sur de curieux alignements de chemins et de monuments en Bretagne', Chronique géographique des pays celtes, in *Annales de Bretagne* (1944), pp. 39–43.

[2] From the *Book of Lecan*, quoted by E. Hogan, *Onomasticon Goedelicum*, p. 126.

A SURVEY OF IRISH AGRICULTURE

WITH SPECIAL REFERENCE TO ITS INTERDEPENDENCE WITH BRITISH AGRICULTURE[1]

by

Dr. J. N. GREENE

I WILL start by giving you very briefly a broad statistical picture of the extent and pattern of our agriculture and its place in our national economy. There are in the Twenty-six Countries roughly 12 million acres of farm land. In all there are slightly more than 300,000 holdings over one acre in extent, and of these 54 per cent do not exceed 30 acres; 20 per cent are above 30 acres and do not exceed 50 acres; 17 per cent are above 50 acres and do not exceed 100 acres, 7 per cent are above 100 acres and do not exceed 200 acres, while 2 per cent are above 200 acres. Farms up to 30 acres occupy 22 per cent of the total area, and those up to 50 acres, 42 per cent of the area. On the other hand, holdings of 100 acres or more account for 32 per cent of the area, while those of 200 acres or over make up 12 per cent of the area. There are about 420,000 men engaged in work on the land, of whom only 60,000 come under the heading of permanent hired workers. It will be apparent to you then that the vast bulk of our land is held in units where the family provide the total labour force.

Of our 11·6 million acres 85 per cent is in grass, and this substantially old pasture. The remaining 1·7 million acres are under tillage crops, providing for the farmer forage and cash crops. By European standards this high percentage of pasture land represents something of a dilemma since as things stand it represents certain trading and economic advantages, but at the same time greatly increases our demographic and social problems. Indeed it represents a system of extensive farming unsuited to small holdings, instead of intensive cultivation as is apparent in other European countries.

Until recently the volume of our agricultural production remained remarkably static, but in recent years has shown a welcome upward trend and the index of volume of production today stands at 112, base year 1938. In terms of gross value our production represents 180 million, a figure which reflects a gross average cash output per acre of only £15. This £15 again reflects the extensive rather than the intensive element in our agriculture, and one which has a tremendous significance when considering the whole economic future of this country. It is of serious concern to our farmers, as indeed it is equally so to all other sections of our community, and it will be necessary to refer to it again later.

Agriculturally based exports represent 85 per cent of our total visible exports as against industry's 10 per cent; of these, cattle and sheep represent 44 per cent. Very roughly, one-third of our production is consumed on the farms, one-third, in our cities and one-third exported.

Our statistics show that those living on the land represent 40 per cent of the population, 38 per cent of the gainfully employed; and receive, including the retail value of farm produce they consume at home, 31 per cent of the national income. They pay 50 per cent of the total national rates after deducting rebates accruing to them, and are assessed for income tax under Schedules A and B. Farmers pay, in rates and income tax, more per pound sterling of income than the rest of the community. This is not generally recognised.

[1] Address delivered to Section M (Agriculture) on September 5, 1957, at the Dublin Meeting of the British Association.

It is clear that the Irish economy is an agricultural economy, and unfortunately our experience of the past thirty-odd years of intensive industrial promotion and development has in no way challenged that position; nor indeed are there any hopeful indications that it can do so in the foreseeable future. Our national prosperity must continue to be linked indefinitely with the productivity of our farms. The best we can hope for in a new approach to industrial development is that much of it can be based on the processing of an increased volume of produce coming off the land, and that the balance will not encroach to the detriment of farm productivity by increasing costs of production.

Enlightened agricultural opinion in the country fully appreciates the urgent need for industrial progress resulting in a more balanced economy, and alternative employment for those who must inevitably leave the land. Migration and emigration from the land are as much part of this twentieth century as the combustion engine and the atomic bomb, and they apply to all countries and not just to Ireland. They will continue because young people growing up are demanding, and rightly so, the opportunities and facilities of their time, and will not accept the alternative, which in effect means isolation and a return to a way of life reminiscent of bygone ages. In the nineteenth-century sense we are a self-sufficient country and in that sense we can more than maintain our present population at home; they would have plenty to eat and a roof over their heads, and if our demands did not go beyond that we would have no problems. Many in this country who are already enjoying a reasonable standard of living emigrate to avail themselves of greater opportunities, and they are increasing in numbers everyday. This trend will continue until our economy ceases to be static in the international as well as the national sense, and such an economy can only be built in this country on a prosperous agriculture. Flight from the land will cease when we can accept in principle, and implement, three important essentials in regard to agriculture:

1. That we see agriculture as an industry, a single industry, and the foundation on which our whole national economic life is based. That the same business principles be applied to agriculture as to any other commercial activity.
2. That as such, agriculture is entitled to remunerate both capital and labour input at rates reasonably equivalent to average current National earnings in other enterprises. In other words, employment on the land whether hired or self-employed must be acceptable, even attractive in the competitive labour markets.
3. That agriculture in essence has long since ceased to provide the most suitable occupation for the less intellectual and indifferently educated section of our people.

Bearing these concepts in mind the expression 'full employment in agriculture' must come within the context of the importance and dignity of the profession to everybody in this country. While appreciating that this type of thinking does not find room for practical expression at the moment I do not think that the day is too far off when such thinking must become a fact.

These are the facts in their simplest form. An acre represents for the farmer an investment of about £100 on a well-stocked and well-equipped holding and assuming that he is fully employed on a 40-acre family farm, an acre represents for himself a labour input of a minimum of £7 10*s*. 0*d*. for himself and another £3 10*s*. 0*d*. for his occasional family help. An acre then must remunerate labour input at £11 and capital at £5, or a total of £16 nett family income per acre. Clearly a gross output of £15 cannot remunerate a nett £16. The maintenance of a married son is obviously impossible, and in terms of a 30-acre holding (the average size), the position is a great deal worse. The inference is that at present farming is either grossly over-staffed or grossly under-paid. Low productivity undoubtedly is a

relevant factor but this aspect can be dealt with later in considering future prospects. In the trade union sense agriculture is pretty well bankrupt, and the result is obvious for all to see; mass migration and emigration from the land and little more than subsistence for those who remain; indeed since 1861 our total population has fallen by one-third and our rural population by a half. If recent levels of productivity were to continue the rural population would require to halve again in order that those remaining could attain a fair remuneration. A static agricultural economy can no longer be tolerated in the face of such facts. If our present labour force on the land is to remain, productivity must at least double. Indeed if one is to take into consideration the artificially competitive and restrictive markets on which our surplus produce must be sold we would nearly require to treble our output. This is the real kernel of our national problems, and one that will not be solved in a climate of accepted national thought, which drains the countryside of its brighter and more intelligent youth, even if these young people are welcome recruits in other spheres more closely associated with the activities of urban pursuits.

Apart altogether from the interests of those immediately engaged in farming, a gross output of £15 per acre is a very serious brake on the Irish people's ability to maintain their present standard of living, let alone increase it. By doubling our production the farmer would get his fair reward, and the economy of the nation as a whole would benefit very much more, since practically the whole of the increased production would have to be exported as we could not consume more than we are at present within the country. In that happy event our agricultural exports could be expected to increase from our present figure of £80 million to a figure approaching or exceeding £250 million, and what a boost that would have on our living standards and all the other things we talk and worry about. I find it stimulating to know that such results could readily be achieved and that our land is even capable of doing considerably better if we can plan and set our minds to achieving it. Had we planned agriculture 30 years ago and allowed industry to develop naturally on a strong foundation of a flourishing agriculture we would not now be in the serious financial crisis that exists today. I do not belong to the school of thought which believes that the vagaries of human nature are such as to make planning in this twentieth century undesirable, I believe it to be essential.

The solution is certainly to be found in increased productivity, but it certainly does not rest in glibly saying to the farmer, 'Increase production', 'Apply more manures', etc., unless we can ensure for him a remunerative market for his produce, and marketing is the great crux of international agricultural trade today. The international situation in which we must market our agricultural produce can be gauged to some extent from this complex background; production and consumer subsidies in Britain which amount to debatable, multiple hundreds of millions a year tend to depress food prices below their economic value on the whole United Kingdom market. Artificially assisted or subsidised exports from practically all other countries in the world are unloaded on to this market. Until a fairly recent change of policy you will have noticed that it cost the Argentine government £53 million on meat exports alone. In America farmers are being paid money to put 11 million acres of land out of production at an annual cost to the government of 700 million dollars, and they have already such colossal food surpluses at the moment that it costs the American people one million dollars a day to store it. Europe itself can be practically self-supporting in agricultural produce, and also has huge price support programmes for home production and strong protection for home producers by means of quotas and tariffs. Our world food markets are no longer competitive in the true economic sense, they are artificial in the extreme. We in this country have very little hope of maintaining regular high-grade exports on these markets unless we can match our competitors in organised marketing skill

and techniques, and get the same large measure of government support and assistance.

All this may not add up to a very pleasant picture for a small nation like ourselves which is situated on the fringe of Europe, involving high freights before we even reach our markets, and a country which is in the course of development and short of financial resources. This may be a shock to those who see in agriculture the solution to under-employment and our demographic problems generally; nevertheless this is the sort of picture in which we must discuss the prospects of substantially improving our national economy through the medium of improved agriculture. Evidence of our success will only be apparent when those engaged in working the land succeed in raising productivity to a point which will reflect a satisfactory incentive income ratio in relation to other forms of procurable employment. It will appear that the people in the world are not prepared to pay the economic value of the food they consume, and they are enabled to maintain this position because of the many influences that have in the past induced farmers to accept the comparatively adverse income position. With the expanding opportunities for alternative employment this position is rapidly changing. It is important that we recognise that even though fewer people are being employed directly on the land, agriculture in its broader sense is expanding its employment potentials in other directions, for example, the production of farm machinery, chemicals, etc. The transfer of labour from the land to this type of industrial activity is eminently desirable but unfortunately, from lack of natural resources of industrial raw materials and scientific developments within the State, the movement is towards those centres of heavy industrial activity in other countries. In this sense we are becoming a less self-sufficient economy by comparison with earlier centuries.

This feature raises the larger issues of the re-appraisal of the advisability of planning our economic development as an isolated unit, or as part of an integrated international or European economy. The mood of present-day thought in the world is less towards narrow nationalism than integration and eventual world citizenship. In spite of what we may do or say the world moves on and this has certain consequences for us whether we voluntarily move with it or not. To move forward our farmers must start by fully appreciating that farming is big business whether you farm one acre or a thousand, and that the largest vested interest they must face today is the mighty force of organised farmers in our competitor countries. Their aggressive policies are geared to anticipate and meet the constantly changing production and marketing problems, which make us look silly by comparison. It is no less important for all other sections of our people to appreciate fully that a prosperous agriculture is not necessarily an evil thing imposed on them by farmers. The pulse by which all of us must assess the economic health of this country is to be found in a prospering rural community. The farmers' contribution to this new prosperity must be, in effect, to become a responsible agent in his own interest. He must see and organise himself as a shareholder and an employee of the country's only vital industry. It is his business to see that the industry appoints and supports its own Board of Management, whose job it will be to conduct its affairs and to ensure for each investor a return on his investment, be it big or small. Farmers who have long awaited their rightful place in Irish society, and an effective voice in the affairs of the country, have never had a better opportunity to contribute from their own ranks and their own resources to a better and more prosperous homeland. The factors that require constant and immediate study and research are:

1. The pattern of marketing, both home and abroad.
2. The pattern of marketing-aids pursued by our competitors.
3. The pattern of our internal and external transport.
4. The pattern of production and productivity.

5. The pattern of price structure, which must at least be related to the economic production costs on the home market. On the export markets we will need, as I have said, to apply at least equal skill and technique as our competitors, while at the same time appreciating that this is not easy for purely agricultural countries such as ourselves.

None of those factors has as yet been adequately determined for Irish conditions—yet they themselves determine matters about which we are already adamant; for example it is precisely these which shall decide what is an economic unit of land and not just some arbitrary figure which somebody has happened to pick out of the blue. An economic unit of land is an acreage which is sufficient to remunerate farm labour and capital at current rates and standards, under reasonably efficient management. On the basis of the present pattern of our agriculture the vast majority of our holdings must be regarded as uneconomic. It is the absence of this much needed research, in relation to our own peculiar circumstances, that produces constant obstacles towards further favourable improvement. The National Farm Survey recently carried out in this country provides our first reasonable attempt even to assess the present situation of agriculture. Though we have started late—very late—much can be achieved in a comparatively short space of time if we can apply ourselves energetically to it.

While we welcome the economic ties we have with the United Kingdom, the weight of recent agricultural policy in Britain has tended to diminish rather than increase their value to us; while at the same time they at least maintain the United Kingdom's preferential position in relation to industrial exports to us. We are in fact among the first three largest importing countries in Europe for the products of British industry and we were top of the list in the year 1955. Because of the United Kingdom agricultural policy, an artificial situation is rapidly developing which is making it uneconomic for exporting countries, and the stronger the economy of any particular exporting country the more readily they can provide aids appropriate to the situation to the disadvantage of weaker ones. The effects of this policy are now being felt further afield so that not only are they weakening for us their home market, they are also starting to make it more difficult for us on alternative European markets. We in this country can visualise a situation arising that may have far-reaching consequences for us and because of that we see with the advent of a European Free Trade Area, prospects that we cannot afford to ignore. At the same time, trade between Britain and Ireland will always be of special importance to both countries, and in the formulation of policy towards European Free Trade cognisance should be taken of the long-standing economic association and complementary nature of the two economies. That association can and should be further strengthened to the benefit of both countries and with the advent of the Free Trade Area it is all the more important, and indeed vital, that Britain and Ireland should harmonise their economic interests in their approach to this important movement for an expanding European economy. If we were to establish an essential interdependence it would be folly not to pursue it to its logical conclusion. The closer integration of European economy is indicative that individual economies, vastly larger than our own, see a threat to their future development if they remain in isolation. For a small economy such as ours to ignore this development would have grave consequences, because our future depends on expanding our markets abroad, and the short-term difficulties thus created must be weighed against the beneficial long-term prospects.

Leaving all political aspects aside and expressing myself on purely economic facts, I approach the subject on the assumption that economic good sense may one day prevail, and in the belief that the people of these islands are linked in a common economic destiny. Benelux and Uniscan have provided an example of

adult and realistic behaviour in that direction within the framework of full political independence, and the Common Market countries show further proof of adult willingness to attempt a far larger and more difficult exercise. Not to apply the same measure of willingness to attempt a relatively easier task in these islands will not reflect very creditably on us as a generation, who must be fully aware of the implications and developments of our time, both for good and evil. Our two countries must inevitably be complementary in so far as even jointly we cannot provide in total our basic agricultural needs; and in terms of industrial potential, expansion could rapidly outpace total available manpower.

While alternatives are available in times of uneasy peace, survival may be problematic in times of less stable conditions. In that unhappy event Irish agriculture will be as important to our joint economy as home agriculture within the United Kingdom. The same will be equally true, and more particularly now with the advent of farm mechanisation, of our agricultural reliance on the products of British industry. It is perhaps too easy to disregard this form of interdependence in times of peace.

But even in peace there is the common ground of our geographical position, language, historically close trading relations, the fact that we too are a mother country and have made an important contribution to the development of Britain and of many countries overseas. We have between our two countries a free movement of money and a free flow of people of which only Benelux and Scandinavia have quite recently provided comparable examples. Under present British agricultural policy, the complementary nature of our two agricultures is reflected only in the arrangements applying to our exports of store cattle, and to a less extent, store sheep to Britain and in these two cases only does our agricultural production reflect any benefits from British home subsidies. On other commodities we have, in fact, lost ground because the benefits of the trade preferences have been appreciably reduced by the fact that British agriculture is now protected mainly through domestic price supports, the effect of which on British production is such that open-market prices have been depressed. Furthermore, some of these preferences, as for example in the case of butter, are specific and not *ad valorem*, so that their value compared with pre-war has declined because of the general fall in the value of money. The position then is that our guaranteed preferences on butter, cheese, eggs, condensed milk, milk powder, cream and live poultry, the *de facto* preferences we have in the case of a number of other products, and our general right of free entry into the British market, are still of value but they have not the same value as when they were negotiated.

Article 1 of the 1948 Trade Agreement with Britain, which is still in operation, reads as follows:

> Having regard to the wish of the Government of the United Kingdom to obtain increased quantities of cattle, eggs and potatoes and to resume as soon as possible the traditional imports from Ireland of bacon, butter, fat sheep and lambs and other agricultural products, and to the desire of the Government of Ireland to increase Ireland's exports and to provide increased supplies of foodstuffs to the United Kingdom:
>
> 1. The Government of Ireland undertakes to use their best endeavours to increase exports of agricultural products to the United Kingdom.

Unfortunately those very desirable objectives have not been attained, except in the case of store cattle and store sheep, largely because of the effects of British agricultural policy. No one, of course, would for a moment deny that it is right and proper for the British government to support British agriculture but it is also true that the manner in which the support is given can have the most widespread international repercussions. In our own case, the effect will be to make our agricultural economy lopsided by removing the incentive towards more intensive

production of pigs, eggs and milk products, all of which are vital activities in a country of comparatively small farms. These remarks are not intended in any way to depreciate the value of the store cattle and store sheep price links, though it has to be remembered that in the case of cattle the Irish government will probably have to spend £10,000,000 to £15,000,000 over the years to come, in eliminating tuberculosis, an essential condition for the continuance of our store cattle trade, and this is a heavy financial burden for a small country like ours.

Our freedom from some of the major livestock diseases is another very important factor in the close association of the agricultural economies of the two countries. We are the only country from which Britain can import live cattle, and one of the few countries from which she can import meat without risk. I understand that the very heavy bills which have had to be paid in Britain in recent years for the compensation for animals slaughtered because of foot-and-mouth disease were largely due to meat imported from overseas. The meat itself may have been cheaper than ours, but the indirect cost is also important.

However we look at it, one cannot but be struck by the close interrelationships between the two economies and by the repercussions which agricultural policy decisions in one country may have on the economy of the other. Our ability to import in the long run depends mainly on our ability to export agricultural produce in greater quantities and here seems to me to lie the possibility of a constructive and mutally beneficial partnership.

I do not think that we should fail to take note of the tremendous economic advantage our emigrants have had in the United Kingdom economy. We in this country regret the circumstances that make it necessary for our people to leave, and see in it not only a social blemish but also a serious economic strain on our resources which is to the advantage and credit of those countries which have opened their doors to receive them. I will not presume to place a financial equivalent on the value of this movement from our country as a form of export but I do not think we should fail to recognise that they have a financial value to the country of adoption.

In conclusion I would like on behalf of the agricultural community to express to the British Association for the Advancement of Science our appreciation of the high honour they have bestowed on us by holding this annual meeting in Dublin, our Capital city. It would appear that men of science and progress, by this very selection of venue, have recognised the basic principle that fundamentally all things have as their base, productivity and development of the soil, on which ultimately we all depend.

PHYSIOGRAPHIC EVOLUTION IN IRELAND

DURING the Dublin Meeting of the Association Section E (Geography) devoted its morning session on Tuesday, September 10, to a group of three papers whose general theme was cognate with that of the Presidential Address on 'The Everlasting Hills' (*Advancement of Science*, XIV, No. 54, pp. 58–67). All three papers endeavoured to recognise stages in the physiographic evolution of Ireland that are potentially datable in terms of geological time. Mr. J. B. Whittow used some rather speculative arguments based on the drainage pattern and summit altitudes in southern Ireland to suggest post-Cretaceous rifting over the site of St. George's Channel to separate Ireland from Wales. Dr. G. L. Davies applied the technique of frequency maxima to the altitudinal data provided by the six-inch maps of the Ordnance Survey of Ireland to reveal a series of possible former base-levels which has points of similarity with the sequence of late Tertiary and Quaternary high sea-levels claimed by workers in Britain and on the Continent. The third paper, by Mr. Nicholas Stephens, examined the formative influences that have made the coastline of north-east Ireland what we see today, and gave evidence of a complexity in which tectonic influences, pre-glacial erosion, glacial and post-glacial oscillations of sea-level, and extensive landslipping have all played a part.

These three papers are summarised below in the order in which they were given.

THE STRUCTURE OF THE SOUTHERN IRISH SEA AREA

John B. Whittow

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The concept of a former land mass over the site of Wicklow, Wales and the southern Irish Sea is well known to geologists. Such a massif certainly existed in Upper Palaeozoic times and is commonly referred to as St. George's Land. Since Wales and Wicklow are now separate, the question arises—when did the southern part of the Irish Sea begin to assume the outline we know today? Three alternative views appear possible:

(1) That St. George's Land 'remained a great positive unit during the Mesozoic and was rarely, if ever, flooded by the sea'. This is the view favoured by L. J. Wills, although he believes that 'in North Wales torsional stresses were relieved by movements along shear-faults', recognising the possibility that the massif was subjected to major earth movements at certain periods of its existence.

(2) That St. George's Land was partly broken up as a result of Armorican fracturing, and Triassic sediments accumulated in the resulting troughs—the Worcester basin in the east, the Cheshire basin in the north-east, and the basins of Liverpool Bay and the Vale of Clwyd in the north. Hill (1955) has postulated a possible fault-bounded basin with a Triassic infilling beneath Cardigan Bay. If this is correct it would imply that an important breach had already been initiated in the Wicklow-Wales massif by the beginning of the Mesozoic.

(3) That partial break-up of St. George's Land by Armorican earth-movements, and the invasion of the Mesozoic seas, were followed by post-Cretaceous uplift roughly following an east–west axis. Nevertheless, if considerable thicknesses of Jurassic and Cretaceous rocks ever capped St. George's Land (and O. T. Jones, 1955, favours this view) there are no proved remnants surviving today either in southern Ireland or North Wales.

The strong suggestion from seismic work that Mesozoic or later rocks occur beneath St. George's Channel appears to invalidate the first alternative, so that the

question is whether or not St. George's Land existed in Early Tertiary times. Since there is evidence of the Plio-Pleistocene 600-foot marine platform along the present Welsh coast St. George's Land had certainly disappeared by late Tertiary times; we must therefore ask what evidence, if any, is there that St. George's Land was ever revivified in post-Cretaceous times. It is possible that a partial answer may be found by a study of the present morphology and drainage of Wales and southern Ireland.

It has long been thought that the major Welsh rivers were initiated on a south-eastward-sloping surface (Lake, 1900; Strahan, 1902; Jones, O. T., 1951), although more recently D. L. Linton has argued for a series of east-flowing consequents. Majority opinion favours an Early Tertiary age for this river pattern on the assumption that it has been superimposed from a Cretaceous cover, which had been tilted by post-Cretaceous uplift. Although O. T. Jones believes that the base of the Chalk must have passed high above the present Welsh summits, D. L. Linton suggests that the highest summits in Wales, northern England and Scotland may represent the position of the sub-Cenomanian plane of unconformity. On this assumption contours of the sub-Cenomanian surface were drawn by Linton and shown to have a prevailing north–south trend in northern Britain. It is here suggested, however, that they show a gradual swing south-westwards on entering Wales, paralleling fairly closely the swing round of the Chalk escarpment in southern England. This would suggest that the major consequent streams in South Wales may have flowed in a south-easterly direction (i.e. at right angles to the contours of the sub-Cenomanian surface). If St. George's Land was in existence in Early Tertiary times, then we might expect to find a similar set of ancient south-eastward- or south-flowing consequent streams in southern Ireland.

Although their views differ quite importantly, J. B. Jukes (1862), A. A. Miller (1939) and A. Farrington (1953) have all regarded the rivers of southern Ireland as flowing originally from north to south, and most workers would agree that the south-flowing rivers exhibit features of superimposition. Since it seems almost certain that the cover rock from which such superimposition may have occurred must have risen over the present mountain tops, an application to southern Ireland of the method used by Linton in Britain in his recognition of the possible position of the sub-Cenomanian surface would be worth making. When this is done, a feature, here termed the 'Kerry-Wicklow Ridge', may be recognised in southern Ireland which bears certain similarities to the British surface (Fig. 1). In the first place the highest section of the 'Kerry-Wicklow Ridge' is at an elevation (3,000+ feet) comparable to the high summit-plane of North Wales. Secondly, a superimposed river pattern is present in both Wales and southern Ireland, the general direction of flow being in a south-easterly or southerly direction. Thirdly, the contours of the 'Kerry-Wicklow Ridge' run parallel to the Chalk escarpment in southern England, and may represent a continuation westwards of the contours belonging to the sub-Cenomanian surface in Wales. Finally, the average gradient of the south-eastward slope of the 'Kerry-Wicklow Ridge' is comparable to the average slope gradient of the sub-Cenomanian surface in Wales (i.e. approximately 25 feet per mile).

From the configuration of the contours it appears that the Ridge, after reaching its greatest elevation along a line from the 'Reeks' to the Wicklows, begins to descend in a north-westerly direction towards the Central Plain of Ireland. It is therefore suggested that while such rivers as the Slaney, Barrow, Nore and Suir were initiated on the south-eastern slopes of the 'Kerry-Wicklow Ridge', the Feale, Deel, Mague and Liffey may be the north-westward-flowing counterparts. A. Farrington (1929) has already demonstrated how the pre-glacial Liffey followed a direction north-westward from the Wicklows.

This brings us to the point where it becomes possible to speculate whether the North Welsh Massif and the 'Kerry-Wicklow Ridge' were once part of the same

land-surface uplifted by post-Cretaceous earth-movements along an arcuate axis from Kerry to North Wales. It is noteworthy that a continuation of this axis eastwards would cross the Chalk escarpment in England at its easternmost limit (i.e. South Lincolnshire), for here along the crest of the uplift the recession of the escarpment would be at its maximum. The question now arises, what has happened to the central portion of this new St. George's Land, assuming that it was uplifted by Early Tertiary earth-movements?

Whilst the Chalk of southern England was folded by the earth-movements associated with the Alpine orogeny, the stresses in more northerly latitudes appear to have resulted in fracturing accompanied by extensive vulcanicity. In western Scotland and northern Ireland we have palpable evidence that the episode was one

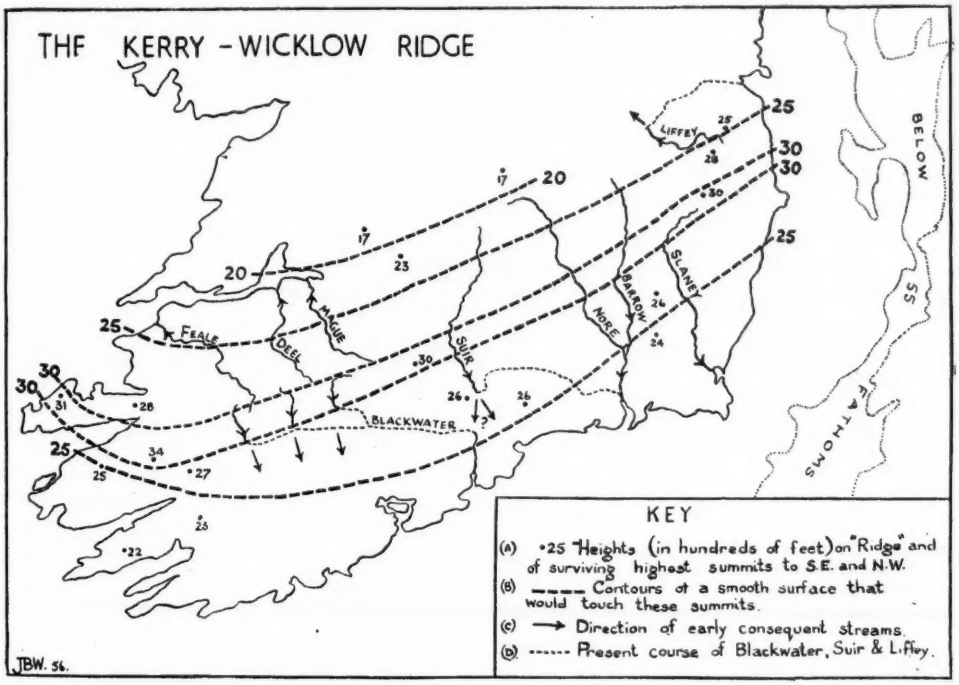

Fig. 1.—The Kerry-Wicklow Ridge.

of considerable earth-movement. It therefore appears possible, as certain Continental geologists have suggested, that the Early Tertiary uplift of St. George's Land culminated in the collapse of its central portion along lines of weakness. Von Bubnoff (1936) and Van de Gracht (1938) were the first to demonstrate the possible limits of a Tertiary rift valley now flooded by the sea, and H. Cloos (1939) compared the Hebridean–Irish Channel rift with those of East Africa and the Rhineland.

In western Scotland and in Antrim deposits of Chalk have been preserved by virtue of the basaltic lava flows which resulted from the Early Tertiary fracturing. In places this Chalk and its overlying basalt have been step-faulted down to and below present sea-level, evidence which would lend support to the theory of a rift structure between Scotland and northern Ireland. Farther south in the Irish Sea, however, the evidence is less convincing; no Cretaceous deposits are present on either shore, though E. Greenly and J. K. Charlesworth have suggested that the Chalk flints in the drifts of Anglesey, Caernarvon and Wexford have been ice-dredged from the floor of the Irish Sea. If, however, Snowdonia and the Wicklows were both carved from the same high-level sub-Cenomanian surface, then the Chalk must

subsequently have been either down-warped or down-faulted in the vicinity of St. George's Channel, so that isolated remnants may still exist on the sea-bed. Preliminary seismic work suggests that a considerable thickness of light-density rocks may be present beneath the southern Irish Sea.

Existing gravimetric data have been plotted on Fig. 2. The most remarkable

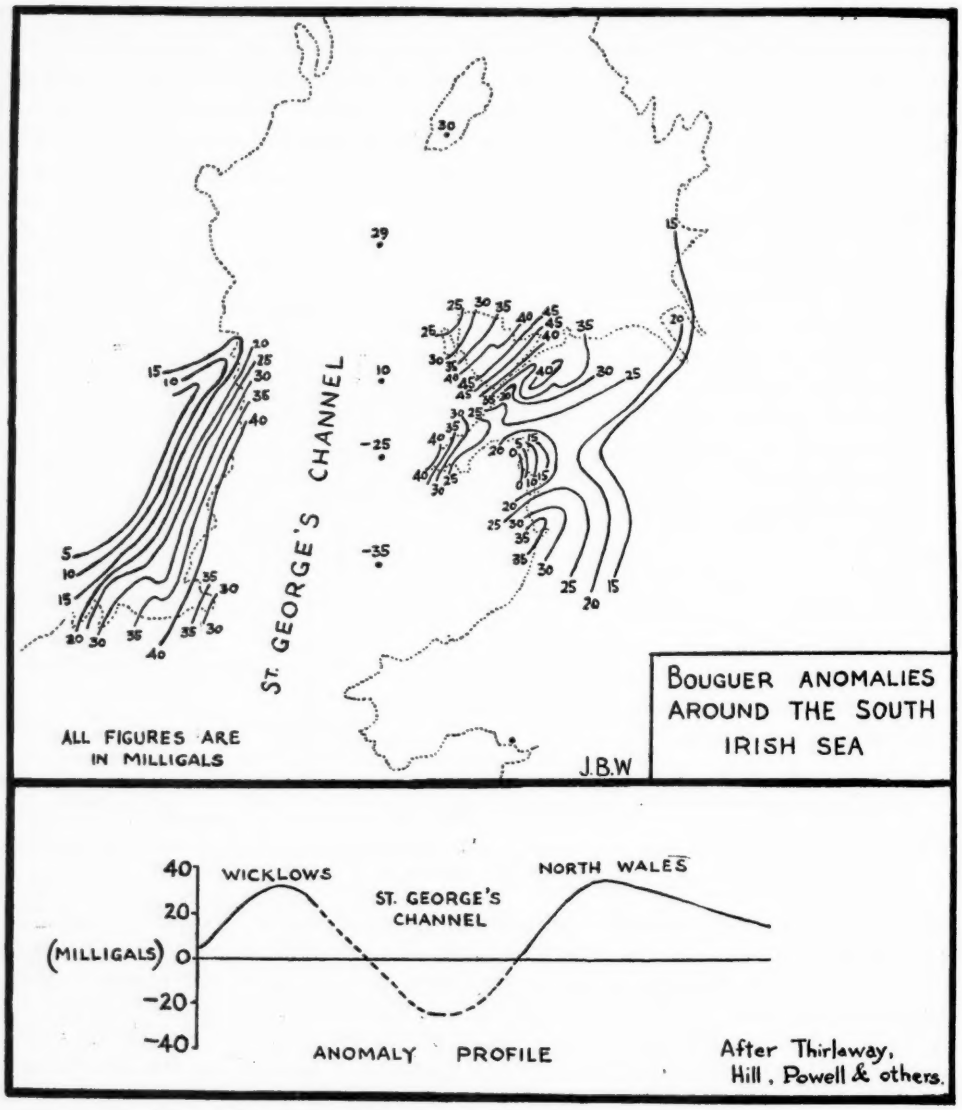

Fig. 2.—Bouguer anomalies around the south Irish Sea.

feature of the anomaly profile on both shores of St. George's Channel is the way in which the anomaly increases as the coastline is approached. In North Wales the anomaly builds up north-westwards to a maximum at the Menai Straits and then drops rapidly towards Holyhead. In Ireland it rises eastwards and reaches a maximum on the Wicklow coast before dropping to the considerable negative anomalies in the centre of St. George's Channel.

This type of profile may be explained by a rift-like structure, a suggestion already advanced by H. I. S. Thirlaway, (1950). A simple rift structure is not suggested by the submarine contours of the sea-bed, although it must be remembered that

those have suffered a great deal of glacial modification. It is more probable that this was a complex zone of fracturing, existing fractures reopening under the stress of continued uplift in post-Cretaceous times. A noteworthy point is that the sudden decrease in gravity anomaly at the Menai Straits occurs exactly where two major faults dominate the structure. Both the Dinorwic and Berw faults have a considerable downthrow to the north-west, quite sufficient to bring down the sub-Cenomanian surface from the Snowdonian summits to sea-level. Although the faults are thought to be of Armorican age, earth-tremors are still numerous in the vicinity (C. Davison, 1924). On the Irish coast there are no major faults with the same significance.

In conclusion, although the author favours a hypothesis based on a rift-like structure, he is aware that certain problems remain to be explained. It may well be argued, for instance, that if St. George's Channel is in fact a rift structure then the major drainage lines should be expected to run in a direction away from the rift, i.e. in Wales east or south-eastward, in Ireland west or north-westward. It has been demonstrated how the drainage of southern Ireland does not follow this pattern, even though the Welsh drainage accords fairly well. Geomorphological evidence alone is powerless to do more than suggest the answers to some of the problems. It is in conjunction with seismic and gravimetric surveys of the sea-floor that a clearer picture will eventually be drawn.

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IRISH EROSION SURFACES—A STATISTICAL ANALYSIS

By G. L. Davies

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Erosion surfaces, or base-levelled plains formed at a time when the sea-level stood higher in relation to the land than it does today, are well-developed landscape features in many parts of Ireland. Unfortunately very few detailed studies of these surfaces have been made, and this statistical analysis was undertaken in the hope that it might yield some information about the number and height of such surfaces in Ireland.

The smallest contour interval on Irish Ordnance Survey maps is 100 feet, and in view of this it was decided not to employ any method of statistical analysis which involved the use of contours. Instead, a graphical analysis was carried out using as data the height of hills and mountains as recorded on the Irish Survey's maps—a method of analysis used by many workers, including Baulig in France and Hollingworth in Britain. It is obvious that if fragments of a once continuous but now dissected erosion surface exist in a region, those fragments will lie at the summit of hills and mountains. Therefore, if the number of summits within a limited range of altitude is plotted against the mean altitude of the range, we have a frequency graph in which the levels of the platforms might appear as maxima. Clearly denudation will have lowered many of the summits to heights slightly below the level of the original surface, and in an endeavour to catch all the summits related to one surface within the same range of altitude various overlapping and non-overlapping groupings were made, ranging from a 10-foot grouping to a 50-foot grouping.

The summit heights used in the study were taken from the six-inch maps which show the height of a large number of trigonometrical stations, the average over the whole of Ireland being about one station per square mile. Not all these stations are

located on hill or mountain summits and all those that were obviously not on peaks were omitted from the study. All other trigonometrical stations were used, and as the six-inch survey is a county survey, and as it was hoped to trace variations in the level of erosion surfaces from one county into another, the thirty-two counties of Ireland were used as the units of study.

Originally it seemed that the larger groupings—particularly the 40- and 50-foot groupings—would be the most useful, for it appeared unreasonable to expect any narrower grouping to contain more than a fraction of all the summit heights related to one erosion surface. It soon became apparent, however, that although the altimetric frequency graphs for any one county might show well-marked maxima and

TABLE I *Southern Counties*

DUBLIN	WICKLOW	WEXFORD	WATERFORD	TIPPERARY	CORK	KERRY	LIMERICK	CLARE	GALWAY	*Total*	*
—	—	—	—	—	—	—	—	—	10	1	—
30	—	30	—	—	30	30	30	—	—	5	6
—	—	—	—	—	—	—	—	—	—	0	5
70	70	—	—	—	70	—	70	—	—	4	4
—	—	—	—	—	—	—	—	—	—	0	4
110	—	110	110	—	110	110	—	110	110	7	7
—	—	—	—	130	—	—	130	—	—	2	9
—	—	—	—	—	—	—	—	150	150	2	4
—	—	—	—	—	—	170	170	—	—	2	4
190	190	190	190	190	—	—	—	190	190	7	9
—	—	—	—	—	—	—	210	—	—	1	8
—	—	—	—	—	—	230	—	—	—	1	2
250	—	250	250	250	250	—	250	250	—	7	8
—	270	—	—	—	—	270	—	—	270	3	10
—	—	290	—	290	—	—	290	—	—	3	6
310	—	—	—	—	310	—	—	—	—	2	5
—	330	—	—	330	—	330	330	330	—	5	7
—	—	350	—	—	—	—	—	—	—	1	6
370	370	—	370	370	370	—	—	—	—	5	6
—	—	390	—	—	—	390	390	—	—	3	8
—	—	—	—	—	—	—	—	—	—	0	3
430	430	430	—	430	430	430	430	430	—	8	8
—	—	—	—	—	—	—	—	—	—	0	8
470	470	—	470	—	—	—	470	470	470	6	6
—	—	—	—	—	—	—	—	—	—	0	6
—	510	510	510	—	510	—	—	510	510	6	6
—	—	—	—	—	—	—	530	—	—	1	7
—	550	550	—	550	—	550	—	550	550	6	7
—	—	—	570	—	—	—	—	—	—	1	7
590	590	—	—	590	590	—	590	590	—	6	7
—	—	—	—	—	—	610	—	—	610	2	8
—	—	630	—	—	630	—	—	630	—	3	5
—	650	—	650	—	—	650	—	—	—	3	6
—	—	—	—	—	—	—	670	—	670	2	5
—	—	—	690	—	—	—	—	690	—	2	4
—	710	710	—	—	710	710	—	—	—	4	6
—	—	—	—	730	730	—	730	—	—	3	7
—	—	—	750	—	—	750	—	—	750	3	6
—	—	770	—	—	—	—	—	770	—	2	5
790	790	790	790	—	790	—	—	790	790	7	9
—	—	—	—	—	—	—	—	—	—	0	7
—	—	830	—	830	—	830	—	—	—	3	3
—	—	—	—	—	—	—	850	—	850	2	5
—	870	—	870	870	870	870	—	870	—	6	8
—	—	890	—	—	—	—	890	—	—	2	8
910	—	—	—	—	—	—	—	—	—	1	3
—	—	—	—	—	930	—	930	930	—	3	4
—	—	950	—	950	—	—	—	—	950	3	6
—	970	—	—	—	970	970	970	—	—	4	7
—	—	—	990	990	—	—	—	—	990	3	7
—	—	1010	—	—	—	1010	—	1010	—	3	6

minima in the larger groupings, those maxima and minima bore little or no relation to the maxima and minima in the graphs for neighbouring counties. This is true even in areas where erosion surfaces are known from field observations to pass from one county into another, as in Waterford and Cork.

A study of the narrower groupings, however, and of the non-overlapping 20-foot groupings in particular, revealed considerable similarities in the graphs for many neighbouring counties, and suggested that the thirty-two counties might be divided into three groups. Firstly, a southern group of ten counties comprising Dublin, Wicklow, Wexford, Tipperary, Waterford, Cork, Kerry, Limerick, Clare and Galway. Secondly, a northern group, also of ten counties, comprising Mayo, Sligo, Leitrim, Donegal, Tyrone, Londonderry, Antrim, Down, Armagh and Louth. The 20-foot grouping graphs for the counties within each of these divisions show sufficient similarities for the counties to be grouped in this manner. The graphs for the twelve remaining counties show few similarities, and they will not be further considered here. It is perhaps worthy of note that most of these twelve counties lie principally on the central Carboniferous Limestone lowland where there is the least likelihood of erosion surfaces having survived.

Table I shows the heights at which maxima occur in the 20-foot grouping graphs for the ten southern counties. The table does not extend above the height of 1,010 feet because there are so few summits above that height in most counties that it is no longer possible to use counties as the units of study. It will suffice to say here that over 1,000 feet the study of summit heights has not been so revealing of high-level surfaces as might have been expected. From the table it is clear that maxima occur fairly frequently at certain heights—rather too frequently perhaps for such accordances to be dismissed as mere chance. The total column records the number of times maxima occur at each height. Again, however, it is hardly reasonable to expect maxima representing erosion surfaces to occur at exactly the same height in

TABLE II

Feet	*Southern Counties*	*Northern Counties*	*Feet*	*Southern Counties*	*Northern Counties*
0– 40	**6**	3	500– 540	7	**8**
	5	6		7	7
40– 80	4	**8**		7	6
	4	7		7	6
	7	4	580– 620	**8**	6
100–140	**9**	4		5	6
120–160	4	**6**	620– 660	**6**	**8**
	4	5		5	6
160–200	**9**	6		4	3
180–220	8	**9**	680– 720	6	**6**
	2	5	700– 740	**7**	4
	8	2		6	4
240–280	**10**	4	740– 780	5	**7**
260–300	6	**9**	760– 800	**9**	5
	5	7	780– 820	7	**9**
300–340	**7**	5		3	8
320–360	6	**10**		5	4
	6	7	840– 880	**8**	**5**
360–400	**8**	5	860– 900	**8**	4
380–420	3	**8**		3	5
400–440	**8**	7	900– 940	4	**8**
420–460	**8**	**8**		6	7
	6	7	940– 980	**7**	8
	6	6	960–1000	**7**	**11**
480–520	6	**8**		6	7

each county, but if the figures in the total column are added in overlapping pairs we obtain a figure which instead of simply showing the number of maxima in every 20-foot range shows the number of maxima in every 40-foot range. These figures are seen in the starred column, and this type of grouping was produced for both the northern and southern groups of counties. The results are shown in Table II.

In Table II the figures in bold type represent the maxima, and there would appear to be a common pattern in the figures for the northern and southern groups of counties. Firstly, there is a series of maxima in the southern counties between 100 and 460 feet apparently corresponding to a series of maxima in the northern counties standing 20 feet higher. Secondly, there is an interval between 460 and 580 feet where maxima appear to be almost absent. This interval is something of an illusion, however, for it exists not because there are no maxima, but because pronounced maxima occur regularly and are evened out as a result of the adding of the overlapping pairs (see Table I). The maxima occurring within this apparent interval show a fair degree of accordance between north and south, but with the northern maxima again tending to be 20 feet higher than those in the south. Finally, over 580 feet maxima again appear in both north and south but with less accordance between the northern and southern groups.

A study of the graphs and of the tables of maxima for the northern and southern groups of counties makes it possible to suggest that erosion surfaces may exist at the heights shown in Table III. The heights indicated are above Irish Ordnance

TABLE III *Heights at which Erosion Surfaces may exist*

Heights in feet above Irish Ordnance Datum

Southern Counties	*Northern Counties*	*Southern Counties*	*Northern Counties*
120	140	550	580
180	200	590	640
260	280	640	700
320	340	710	760
380	400	780	800
430	440	870	920
470	480	970	980
510	520		

Datum, which is just over 8 feet below mean sea-level, and represent the mean heights of the possible surfaces. Up to about 510 feet a series of eight surfaces may exist in the southern counties, and these surfaces would appear, from the statistical evidence, to have counterparts in the northern counties lying between 10 and 20 feet higher. Above 510 feet the statistical evidence suggests the existence of seven surfaces in both north and south, but the relationship between them, if any, is not clear.

Whether the various maxima in the altimetric frequency graphs do in fact represent erosion surfaces is a question that must remain unanswered for the moment because of the lack of field studies of the Irish surfaces against which to compare the statistical results. Certainly there is little similarity between the statistical results for County Down and the surfaces mapped in the Mourne Mountains by Proudfoot (1). In the Burren region of County Clare, however, it would seem that the statistical results do bear some relationship to the results obtained by Sweeting from field mapping of the surfaces (2), but even here there are a number of maxima in the graphs which do not correspond to surfaces identified in the field. The results of the statistical analysis are therefore inconclusive, and only further research in the field can show whether any of the maxima in the graphs do in fact represent erosion surfaces.

1. PROUDFOOT, V. B. (1954): 'Erosion Surfaces in the Mourne Mountains', *Irish Geography*, Vol. III, 26–35.
2. Sweeting, M. M. (1955): 'The Landforms of North-West County Clare, Ireland', *Institute of British Geographers, Transactions and Papers*, 33–39.

THE EVOLUTION OF THE COASTLINE OF NORTH-EAST IRELAND

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The coastline of north-east Ireland is for the most part aligned along a series of major tectonic features of Hercynian and especially Tertiary age. Both Lough Foyle and Strangford Lough are in part related to fault-guided depressions in the Pre-Cambrian or Palaeozoic basements, which contain Carboniferous as well as Triassic strata. Between Lough Foyle and Fair Head the coast appears to follow a zone of tension or tectonic weakness which is indicated by east–west trending faults (mainly post-basaltic, but including some posthumous dislocations) and numerous volcanic plugs and vents which are intersected in the modern cliff-line. The North Channel trough is in itself a major tectonic depression (Wright, 1919; Cook & Murphy, 1952) defined by multiple post-basaltic faulting on its western side along the edge of the Antrim Plateau, where many of the individual faults downthrow to the east. The run of the submarine contours supports the view that this steep-sided submarine feature is fault-guided and that it extends south-eastwards between Down and Galloway, where the geological evidence for multiple faulting is absent. The changing trend of the Down coast between the tip of the Ards Peninsula and the fault-guided inlet of Carlingford Lough may reflect the reimposition of the Caledonian trend lines.

With the outline of much of north-east Ireland determined by post-basaltic fracturing the evolution of the coastal morphology has resulted in the formation of contrasting coastal profiles across a variety of geological formations. Long gentle slopes and bevelled cliff profiles are revealed on the Palaeozoics where the glacial drift is thin or absent in County Down. There is more pronounced bevelling on the Old Red Sandstone and schists in north-east Antrim, where over a limited segment of the coast true hog's-backed cliffs may be distinguished. The severe ice scouring of these resistant formations has not obliterated their pre-glacial profiles, which appear to owe their formation to a combination of marine attack and especially to long-continued subaerial denudation. There is a striking contrast with the cliffs developed across the Mesozoic clays and limestone (Chalk), and the Tertiary lavas with their inter-basaltic horizons. Here the dominant cliff form is stepped or multi-scarped in profile, across the gently dipping bedding planes of the chalk and lava tiers, but over considerable stretches of the coastline, especially along the east coast of Antrim, major landslips and sludging have occurred. The big landslips are fault-guided and have allowed slices of the plateau to subside seawards over the lubricated surface of the Liassic clay, but may maintain the stepped outline of the cliff if the slipped block retains its shape, as for example at Garron Point. Where the slipped blocks break up, or are not fault-guided, sludging of a mixture of chalk and basalt blocks within a matrix of finely divided basalt and clay takes place over the Liassic clays and Triassic marls, forming a chaos of moving streams or sheets of material in an exceptionally mobile condition. There is every reason to regard most of the detail of the stepped profiles as post-dating the last major glacial advance and retreat, and it seems likely that freeze-thaw action in the late-glacial phases has triggered-off not a few of the smaller landslips, and has been responsible for some sludging.

The glacial drifts provide direct evidence of the 'pre-glacial' age of the coastal slope at many points, and establishes beyond doubt that the general outline of north-east Ireland was an accomplished fact before the Pleistocene period began. But whereas in Londonderry and Antrim the high cliff forms dominate the scenery, in County Down there has been considerable progradation of the coastline by the

accumulated drifts. Much of the Ards Peninsula and Lecale would become an archipelago of rocky islands if the glacial drifts were removed.

Probably the oldest Pleistocene feature is a wave-cut rock platform, the height of which is about 30 feet at the cliff notch, whose surface has been glaciated, but whose precise age is as yet unknown. It seems to be mainly confined to the Down coast (it is also known to underlie the deposits of two glaciations, Saale and Weischel, on the Wicklow and Wexford coasts), but this does not mean that it was never formed in County Antrim, where it may not have survived the successive glaciations in a recognisable form, or has been removed by later marine erosion where originally cut in the weak basalts. There is a distinct possibility that the same platform is present on part of the Inishowen coast.

Buried channels cut in rock in Lough Foyle, Belfast Lough and Strangford Lough probably indicate low pre-glacial or early Pleistocene sea-levels. They may be

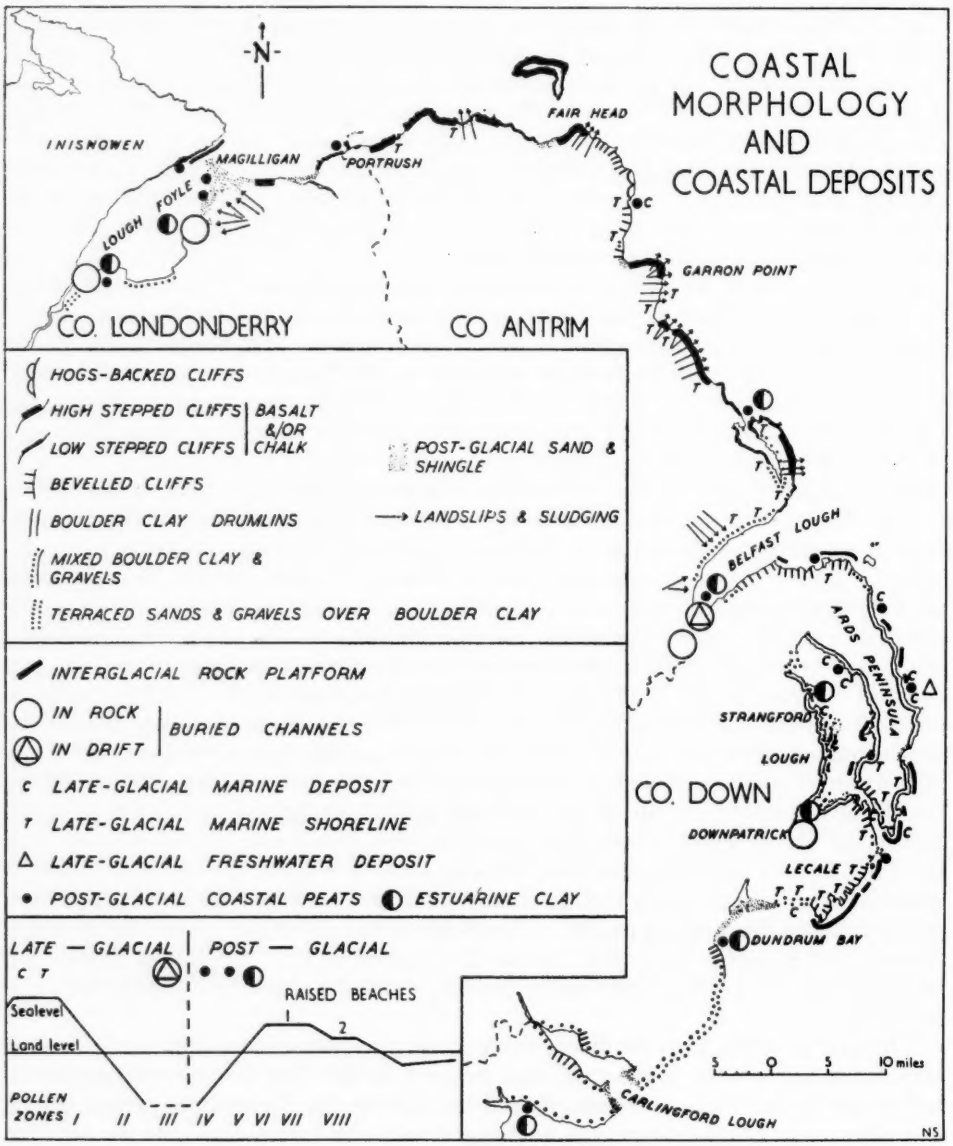

Fig. 1.—Coastal morphology and coast deposits.

tentatively correlated with the buried rock channels of the Clyde, Mersey and Liffey in the Irish Sea Basin, but it cannot yet be stated with certainty that the buried channels pre-date the rock platform.

Traces of raised shorelines remain around the coasts of north-east Ireland, post-dating the last withdrawal of the main Scottish and Irish ice sheets. A late-glacial sea-level (benches cut in drift and marine clays provide the evidence for its height; it is placed either just prior to, or within, Zone I in County Down) is found at 45–65 feet O.D. in Down but between 70 and 100 feet O.D. in parts of County Antrim. It seems unlikely that the marine terraces in County Down need be exactly contemporaneous with those in Antrim, and still less that both sets can be precisely correlated with similar features in western Scotland. A tentative time-table (in terms of Pollen Zones) for the late-glacial and post-glacial fluctuations of land and sea-level as eustatic and isostatic movements of sea and land took place, is indicated in Fig. 1. There is considerable evidence, from an analysis of borehole records at Belfast and from a site in the Ards Peninsula where fresh water sediments of Zone 2 age are found below modern high-water mark, to suggest that a phase of low sea-level occurred between the late-glacial and the post-glacial marine transgressions. At the maximum of the post-glacial transgression considerable areas were inundated around Strangford Lough and Lough Foyle, and much of the southern half of the Ards Peninsula was converted into a series of lagoons and islands. The peninsula of Lecale was probably cut off from the mainland by a water channel extending from Downpatrick to Dundrum Inner Bay.

The analysis by Mrs. McMillan (1957) of the faunal content of the shell banks and raised beaches around Lough Foyle suggests that Magilligan Foreland was probably not in existence at the time of the maximum of the transgression, but perhaps began to be formed during the second recovery stage indicated by the lower raised beach, which seems to constitute the greater part of the foreland. This second beach, which is also known on the Down coast, indicates a definite pause in the progress of the recovery of the land following the main post-glacial transgression, and it too may be slightly down tilted from north to south, but less so than its predecessor. Raised rock shelves constitute most of the evidence for the transgression along the steep Antrim coast, but they are by no means continuous features, having been cut away and replaced by modern wave-cut platforms which are still forming at the present time, especially in the softer basalts.

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SCIENCE IN SCHOOLS

THE British Association for the Advancement of Science is proposing to hold a Conference on Science in Schools in the Hall of the Royal Geographical Society, London, on April 17th and 18th, 1958.

The purpose of the Conference is to consider the urgent problem of the supply of scientists and technologists in this country as well as the need for science as an integral part of general education, it being the belief of the British Association that a person ignorant of science is handicapped in this modern world. The Headmasters' Association is also deeply concerned about this problem, and in particular about the supply of science teachers and the provision of adequate laboratory equipment in many schools. A recent survey suggests that over half the maintained schools cannot expand their sixth form science teaching without additional laboratory accommodation, and in view of the expected increase in the school population in the early 1960's, this problem is likely to become even more acute.

The Conference will be opened by Lord Heyworth and Lord Tedder will sum up during the fourth session. The Chairmen of the sessions will be Sir Ben Lockspeiser, Mr. F. L. Allan, Mr. M. G. Bennett and Sir Raymond Priestley and the principal speakers will include Sir Solly Zuckerman, Sir Eric James, Miss E. M. Huxstep, Dr. A. W. Barton, Dr. H. F. Boulind, Dame Kathleen Lonsdale, Dr. D. R. Chesterman, Dr. J. W. F. Hill and Dr. B. E. Lawrence. In its first session, the Conference will consider the national need, science as a component of general education and scientific education for girls. The present position as regards the supply of science teachers and the provision of accommodation and equipment for the teaching of science in schools will be presented in the second session by speakers with first-hand knowledge of the problems, together with a review of what has already been done. The second half of the Conference will be devoted to the consideration of ways and means to meet the need. The role of the Universities and Teachers' Training Colleges in the supply of teachers and that of the Local Education Authorities in providing accommodation and equipment will be discussed.

It is expected that the Conference, which has been approved by the Minister of Education as an educational conference for the purpose of Section 83 of the Education Act 1944, will be attended by representatives from a wide range of educational bodies, from Local Education Authorities and also from the Universities and Industry.

A programme and form of application for tickets may be obtained from: The Secretary, British Association for the Advancement of Science, Burlington House, Piccadilly, London, W.1.

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